UNITED STATES DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

Brief Instructions on Methods of Gully Control

by

C. E. Ramser, Senior Drainage Engineer

Prepared under the direction of Lewis A. Jones, Chief
Division of Drainage and Soil Erosion Control
Bureau of Agricultural Engineering
S. H. McCrory, Chief
August, 1933

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NATURE OF GULLY CONTROL WORK

In an extensive program of gully control it is primarily important that one keep in mind the permanence of the gully improvements. For instance, if the check dams are built of material that has a comparatively short life, it becomes necessary to provide annual maintenance and perhaps renewal after a few years. Even control structures built of permanent materials require a certain amount of care and maintenance as insurance against possible failures. Check dams built of straw, brush, poles and logs, woven wire, and loose rock usually have a comparatively short life, while dams built of rock or stone masonry, concrete and earth, are of a more permanent nature.

In order to make the results of the work effective, in its application to flood control, it is important that control work be not scattered in a hap-hazard manner over the entire area served by each camp, but that it be confined to a definite watershed. The ideal plan would be to start at the upper end of a watershed and complete all gully control work needed on the watershed, proceeding down stream. A progress map should be kept by the camp superintendent, showing progress and amount of work done on each watershed.

All work done should have some relation to flood control, which may be the result of causing more water to penetrate the ground surface; of preventing the washing away of soil that later is deposited in drainage channels, thereby reducing their capacity and causing overflows; or the storing and holding back of water with the intention of reducing the frequency and duration of floods in nearby bottom lands.

In order that the most effective results and lasting benefits are derived from this program of gully control work, it is important that only such work as is specified below be undertaken: -

1. The construction of large earth, masonry or concrete soil-saving dams capable of controlling and filling large gullies, (where the slope is comparatively small and a large amount of storage for water and soil above the dam is created) or at the upper end of a large gully, or an incipient lateral gully where the slope is quite steep to prevent the extension of the gully and the destruction of good land or damage to valuable property.

2. The installation of vertical inlet pipes or boxes at upper ends of highway culverts under high embankments to form large soil-saving dams. This work is to be done with the written consent and cooperation of the county or state officials.

3. The building of check dams of material of a permanent character in small gullies and terrace outlet ditches. Work of this nature should be given preference over the building of temporary dams, whenever the material, such as rock, is available and, on account of the permanent nature of such structures, vegetative work, although desirable, is not required for the permanent protection of the gullies.

4. The building of earth fills where terraces cross large gullies (not less than 3 feet deep) only after the terraces have been constructed. The terraces should be properly laid out and constructed and should conform to recommendations given in Farmers' Bulletin No. 1669, or to state publications on terracing. Under no circumstances should such earth fills be built prior to the construction of the terraces.

5. The construction of check dams of a temporary character in gullies for the combined purpose of filling the gullies and to assist in establishing vegetation that will prove effective in controlling the gullies after the check dams become ineffective. Vegetative methods of controlling the gullies should be started immediately, or the landowner should promise faithfully to employ such methods at his first opportunity, and there should be every assurance that the vegetative method, as planned, will be effective in controlling the gullies. Under no circumstances should dams of a temporary character be built in gullies where no revegetative work is planned. While check dams of a temporary character are, of course, effective in controlling erosion in gullies, even where systematic vegetative methods are not employed therewith, provided they receive regular annual maintenance and occasional renewal, it is not believed that sufficient assurance can be given that this will be done because of the possible change in landowners, a dwindling of interest, or some such cause.

6. The building of overfall protection works to prevent the beginning of a bad gully or to control the possible extension of existing gullies and their laterals. These overfalls should be built of permanent material where needed permanently and may be of temporary material where built in connection with a large earth soil-saving dam, the object of which is to fill the gully so that a high permanent overfall would not be needed. A lower overfall of a permanent character may later be built if found necessary.

7. The construction of diversion ditches that have for their purpose the leading of water away from the heads of the gullies, thus preventing the drop of the water into the gully with its attendant destructive erosive power.

METHODS OF GULLY CONTROL

Methods of controlling and reclaiming gullies are given in Farmers' Bulletin No. 1234, entitled "Gullies - How to Control and Reclaim Them." Additional instructions are given herewith to supplement the information given in the bulletin. More details are given in the accompanying drawings of the check dams. Curves are included for use in the determination of the sizes of culverts through soil-saving dams, and tables for determining the sizes of notches and spillways in check and large soil-saving dams. Also, it is believed that in the present program, erosion control structures should be built safer than is the usual practice, owing to the fact that the manner in which they will be maintained is rather indefinite. This has accordingly been kept in mind in preparing the accompanying recommendations for check and earth soil-saving dams.

CHECK DAMS

Check dams have for their object primarily the control of gullies to prevent their extension or enlargement and do not, as a rule, collect an appreciable quantity of soil above them. They are particularly adapted for use in small gullies with comparatively small drainage areas and small run-off. Where they are employed to reduce and control the cross-section of a needed channel draining a comparatively large area, only permanent types of check dams should be used, and more care should be exercised in their construction than when used in gullies with small watersheds.

Dams of porous material, such as brush, logs, loose rock, and woven wire, should, as a rule, be limited to a height of 2 or 3 feet, but may be built as high as 4 feet only when exceptional conditions require such height. The hydraulic pressure of the water on dams increases directly with the height so that the greater the head of water, the greater the tendency to force deposited material through the porous structure of the dam during heavy rains. In general, it is cheaper and more satisfactory to reclaim small gullies with low rather than with high dams, regardless of the nature of the material used in construction.

Spacing of check dams in a gully should be such that the fill which accumulates in the gully above the dam extends to the foot of the next dam above. The fill will usually assume a slope of from 6 inches to 12 inches per 100 feet, depending upon the nature of the soil, if there is no vegetation in a gully. With vegetation present, the fill of course will assume a much steeper gradient, depending upon the density and nature of the vegetation, but to be on the safe side, it is advisable not to rely upon vegetation to maintain a steep gradient.

Particular care must be given to the construction of the check dams at the upper and lower end of a gully. At the upper end the check dam should be built as close to the head of the gully as possible so as to fill the upper end of the gully and prevent any further eating upstream. Mattresses of brush and rock, held by woven wire, box troughs built of creosoted lumber or galvenized metal, and aprons of concrete or masonry are all very effective where the fall into the gully is not too great as is generally the case where check dams are built. The design of check dams built of brush and rock, shown in the accompanying figures, can be modified to suit conditions of overfalls at the head of gullies.

In the construction of a check dam at the lower end of a gully it is especially important to examine conditions affecting the stability of the bottom of the gully. If there is a tendency for the gully to increase in depth due to uncontrolled conditions below such as may exist in a large drainage channel, it is necessary that the floor of the apron below the dam be placed deep enough to forestall the possibility of undermining due to probable future changes in controlling conditions below.

From the discussion on hydraulics of erosion control, (page 15) it apparently is important that the drainage area and the water running off be determined before the construction of erosion control structures. The proper size of notches or weirs in the check dams to prevent overflowing of the dam or gully depends upon a correct knowledge of the probable

maximum rate of run-off from the drainage area and the water carrying capacity of the notch or weir. These subjects are treated in detail under the discussion "Hydraulics of Erosion Control." (page

In the construction of check dams, special attention is called to the necessity of giving careful consideration to the following important points: -

1. The reduction in cross-sectional area of the gully should not be so great as to cause the run-off water to overflow the banks of the gully and thereby cause erosion around the ends of the dam or the development of a new parallel gully down the slope.

2. The ends of the check dams of a watertight character should extend far enough into the gully banks to prevent the possibility of water seeping around the ends and causing the washing away of the side of the gully.

3. The foundation of the bottom of the dam should extend far enough below the bottom of the gully to prevent the hydraulic pressure from forcing water under the dam and thereby undermining the structure.

4. The top of the dam should be low enough in the middle and the sides of the dam should extend high enough up the banks of the gully so that the water flowing down the gully never exceeds in height the upper part of the sides of the dam.

5. An apron should be provided in the floor of the gully below the dam, of sufficient dimensions in both length and width, to prevent any erosion or undermining of the dam from the water dropping over.

Drawings of a number of check dams, built of a variety of materials, are shown in figures 1 to 9, and brief descriptions of these dams are given below.

Figure 1.- The method of building brush dams shown in this figure is employed when considerable brush is available. In building this dam, the side and bottom of the gully, for a distance of 10 to 15 feet along the gully, is covered with a layer of straw. The brush with butts pointing upstream is laid close together on the straw and thoroughly tramped down, the fine brush being placed at the bottom and the coarser on top. Several rows of stakes about 2 feet apart in and between the rows are driven in the bottom and sides of the gully. The gully is partly filled with brush before the stakes are set in place and lightly driven in. Sufficient brush to complete the dam is then placed and heavy galvanized wire is stretched along the rows of stakes and fastened to them. Finally, the stakes are driven in until the wire holds the brush firmly in place, the dam being made lower at the middle than at the sides of the gully by driving the stakes accordingly.

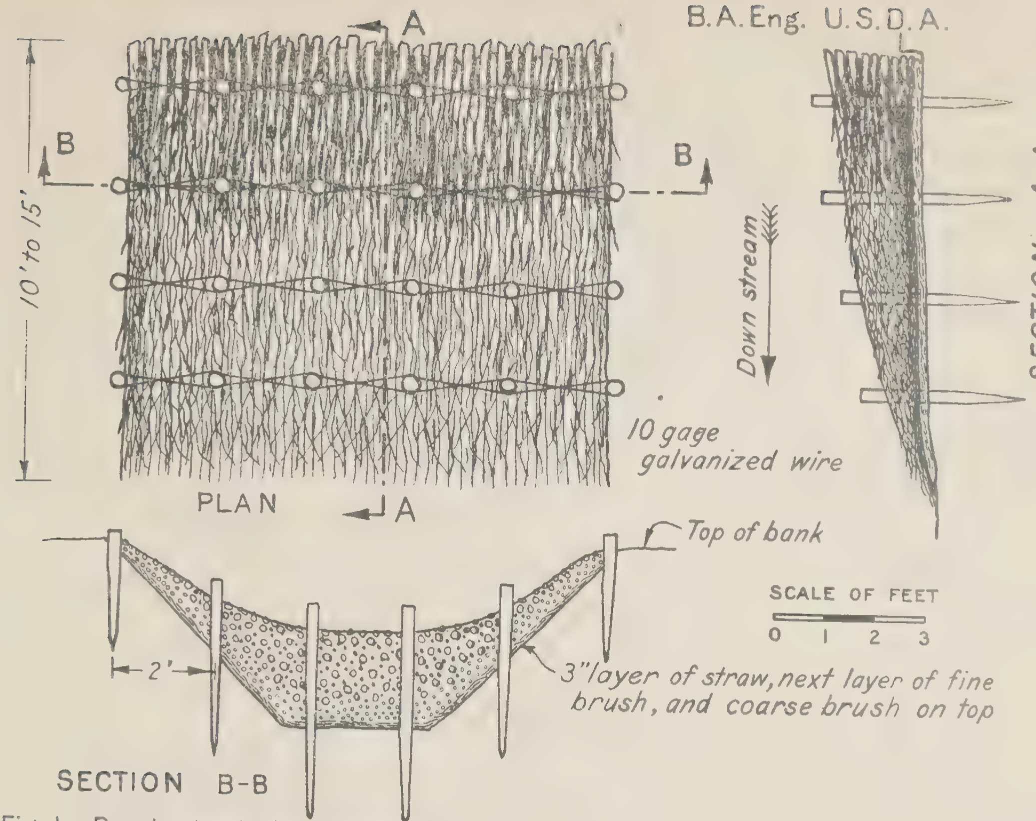

Fig. 1.—Brush check dam anchored with stakes and wire (brush parallel to gully)

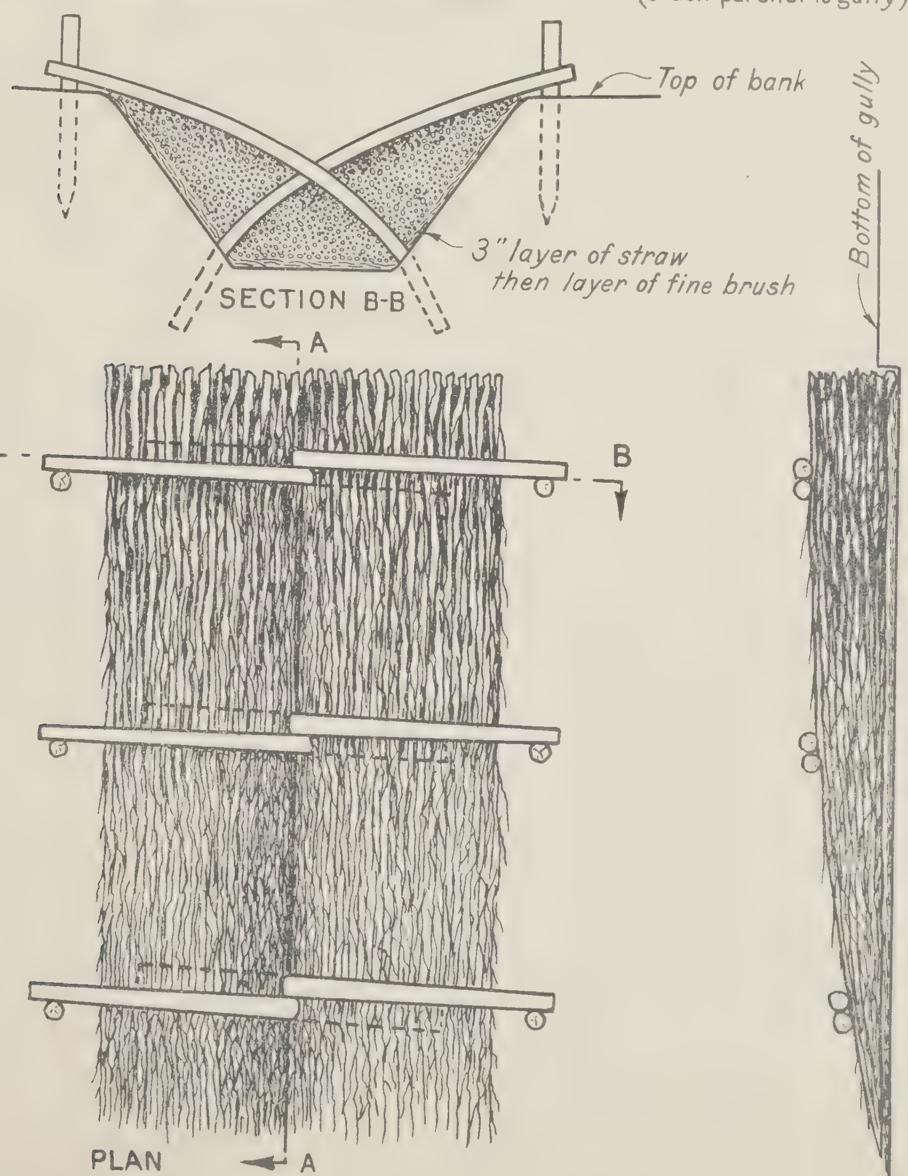

Fig. 2.—Brush check dam anchored with cross poles

Figure 2. The brush dam in figure 2 is similar to that shown in figure 1 with the exception of the method of anchoring, which should be employed where rock is encountered in the bottom of the gully, or the ground is too hard to permit of driving stakes. Straw and brush are first placed in the bottom of the gully for a distance of 10 to 15 feet. Small poles 3 or 4 inches in diameter are set diagonally into the lower part of the bank on both sides of the gully 3 or 4 feet apart, and are bent over to the top of the opposite bank and fastened by means of wire to stakes driven in the top of the bank. The larger end of the poles is set into holes in the ground, dug with a crowbar or post-hole digger, at such an angle that the holes from opposite sides cross 2 or 3 feet above the bottom of the gully. The brush is then laid between the lower parts of the poles and under the upper parts, so that when the tops of the poles are bent down it will be held compactly and securely and will be lowest in the middle of the gully.

Figure 3. The type of brush dam shown in this figure is generally built in large gullies and requires less brush than the two types of brush dams shown in figures 1 and 2. In building this dam, two rows of posts, preferably hedge, 4 to 6 inches in diameter, about 3 feet apart, are set to a depth of about 4 feet in the bottom of the gully. The bottom of the gully is then covered with a layer of straw and then a layer of fine brush, and coarser brush is laid crosswise of the gully and into the sides for a distance of 3 or 4 feet. An apron below the dam for the water to fall on is formed by laying brush across the dam with tops downstream between the layers of the brush laid across the gully. Long brush is laid near the bottom of the gully and shorter brush higher up, which forms an apron with a gradual descent for the water. The brush should extend to the top of the banks and should be considerably lower in the middle than at the sides, depending upon the size of the drainage area. This type of dam is not recommended for heights greater than 4 feet, and the upper row of posts should be anchored by wire to buried logs upstream when the drainage area is large.

Figure 4. The check dam shown in this figure is built of logs or large poles. In building this dam, posts are set in a row across the gully about 4 feet apart and 4 feet deep. A trench is then dug on the upstream side of the posts, extending about 2 feet into the sides of the gully. A log is laid in this trench, which is deep enough to bury it, and other logs are laid on top of the first, until the top log is as high as the top of the posts. Straw or grass should be placed between the logs to fill crevices and to assist in catching and holding silt in these openings. The logs are held in place by spiking them to the posts, or by driving small stakes on the upper sides at the ends of the logs. Dirt should then be piled on the upper side of the logs with a surface slope of about 2 to 1, the idea being to make the dam practically watertight. A notch is cut out in the center to provide for run-off water, or short logs are used on each side at the top to provide the necessary opening. An apron of logs, poles, or stone is built below the dam and should be several feet wider than the width of the notch, and the full width of narrow gullies. It should be about 1-1/2 times as long as the height of the dam. Where logs or poles are used, they can be held in place by extending one end under the dam and fastening the other end down with a cross pole spiked to stakes driven into the ground on each side of the apron, or a rock apron may be constructed. As a general rule these dams should not exceed a height of 4 or 5 feet.

Figure 5. The woven wire dam shown in this figure consists essentially of a low fence across a gully. The common method of building these dams consists of setting a row of wooden or steel fence posts across a gully about 4 feet apart. The posts should be set at least 4 feet deep and should be anchored by wire to posts, as shown in the figure. A trench about 6 inches deep should be dug along the upper side of the posts and the lower 6 inches of the wire buried in the ground. This type of dam is suitable for use in shallow gullies with small drainage areas and should not exceed 2-1/2 feet in height at the center. In order to promote rapid filling, straw should be packed in above the dam to the height of the crest. Rock, if available, is usually placed below the dam to prevent erosion. If the dams are placed close together so that a fill is backed up to the next dam above, an apron may not be necessary.

Figure 6. The woven wire check dam, shown in this figure, is also recommended for use in small gullies with the depth below the low part of the crest not exceeding 2 or 3 feet. Two posts are set on either bank about 5 feet deep, and a cable or several strands of twisted wire is suspended between the posts, being attached to the posts as near the ground as possible. For spans between the posts of more than 8 feet, the posts should be anchored back at right-angles to the gully by means of wire fastened to buried logs or substantially set posts. That part of the woven wire which extends up the bottom of the gully depends temporarily for its anchorage upon a log buried in the bottom of the gully, as shown in the figure. As soon as a fill is caught in the gully, it will automatically serve to strengthen the anchorage. The woven wire on the side slopes is anchored by means of small stakes. To assist in the rapid filling of the gully, straw, or some such material, should be packed in above the dam as high as the crest. Loose rock may be placed below to prevent erosion. However, these dams are usually placed close enough together so that an appreciable fill occurs in the gully between the dams and an apron is not required to prevent erosion below. Also, should erosion occur, there is little danger of undermining, due to the flexibility of woven wire in adjusting itself to any change.

Figure 7. In this figure is shown a lumber or plank check dam. This may be built with either ordinary or creosoted lumber. Where the gully is to be controlled by revegetation later, ordinary lumber is satisfactory, but where the control of the gully requires permanent dams, creosoted lumber should be used. These dams are usually built 2 or 3 feet high at the crest, and should not exceed a height of 4 or 5 feet. Owing to the depth that the planks are set in the ground, there is not much danger of undermining low dams of this type. An apron of loose rock is desirable for heights of 4 or 5 feet. The planks are set in the ground and not driven, as it is usually difficult, particularly in hard soil, to make a watertight connection between planks when driven. The construction details of this dam are given in the figure.

Figure 8. In this figure is shown a rubble masonry dam which is a very desirable type of check dam, where rock is available. The rock should be very carefully laid and ordinarily for heights of 2 or 3 feet, concrete work will be required only in the outer shell or layer of rock including the spillway. Soft rock should not be used. For higher dams, the higher water pressure makes it advisable to lay all the rock in cement. This type of dam is particularly adapted for use in gullies that

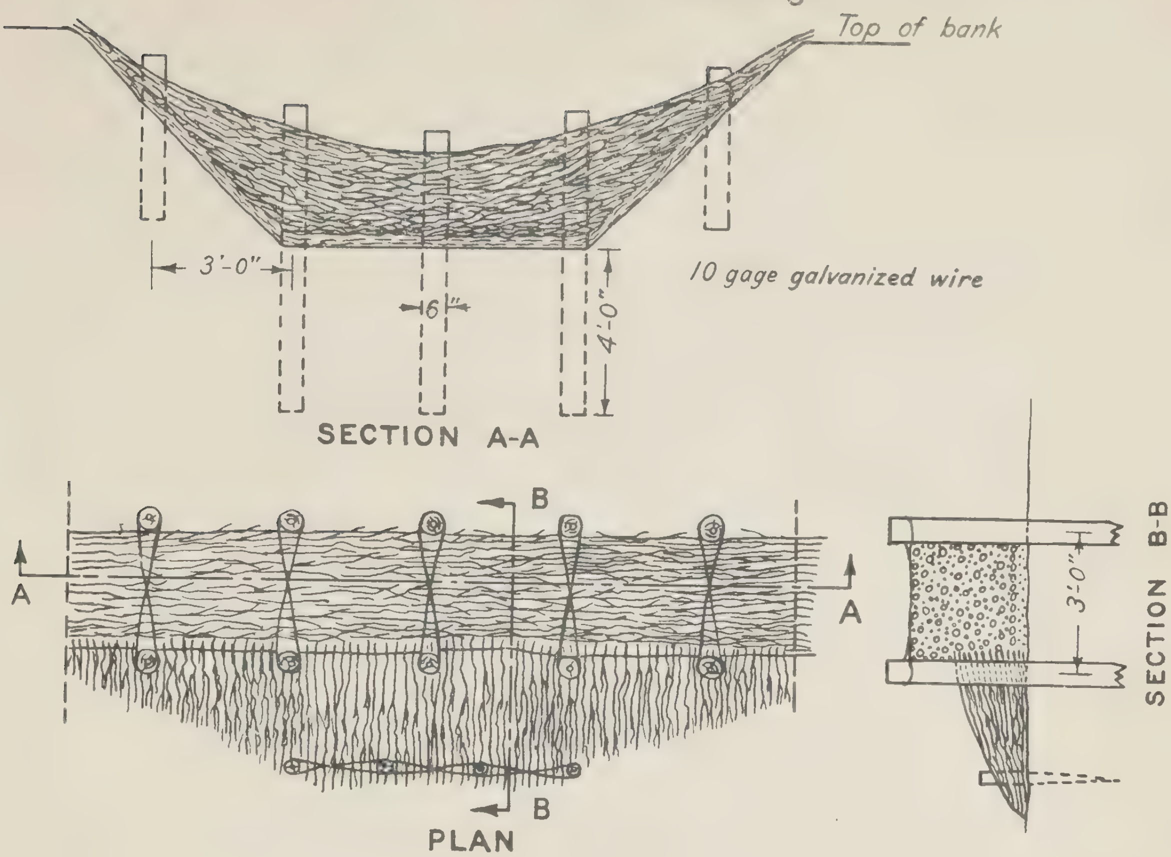

Fig. 3.— Brush check dam anchored with posts and wire. Brush laid across gully

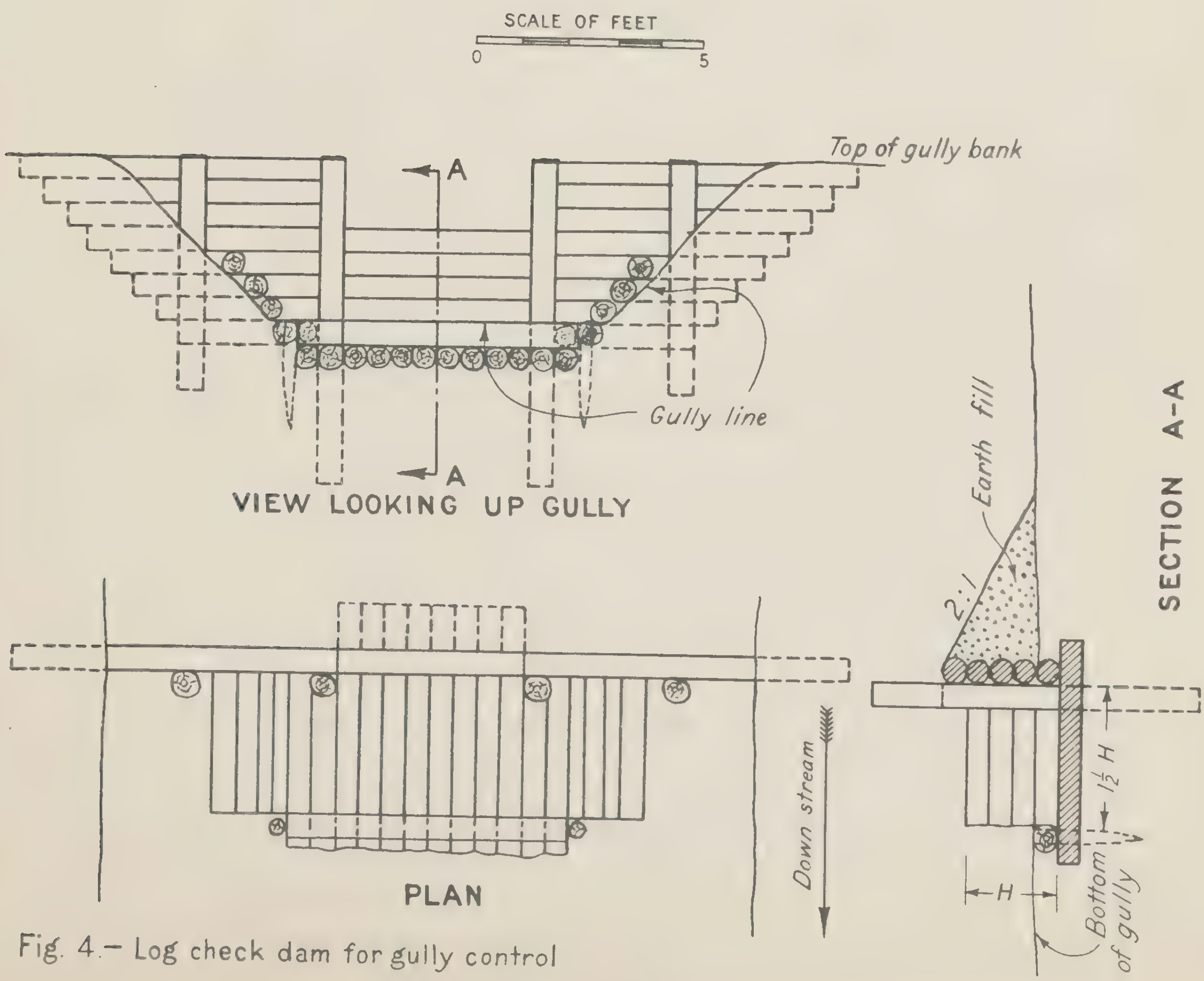

Fig. 4.— Log check dam for gully control

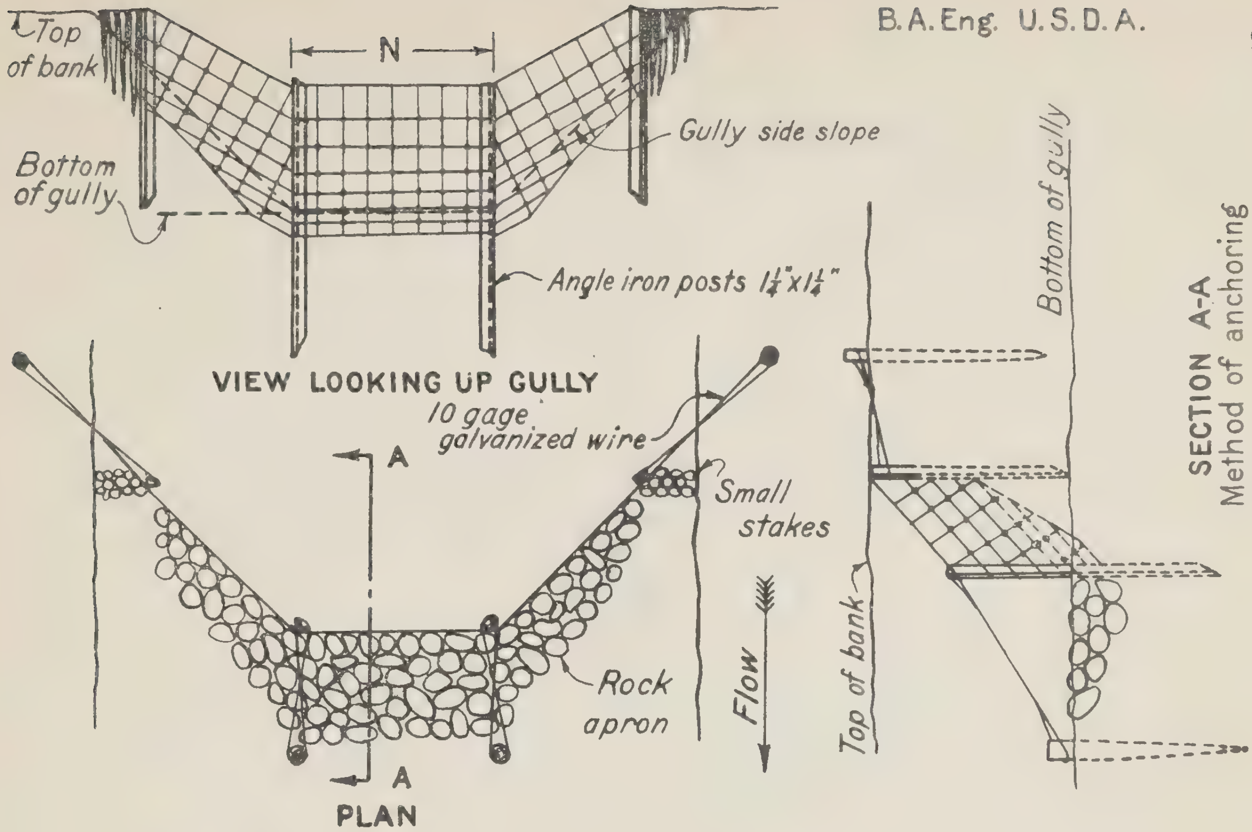

Fig. 5.– Woven wire fence check dam for gully control

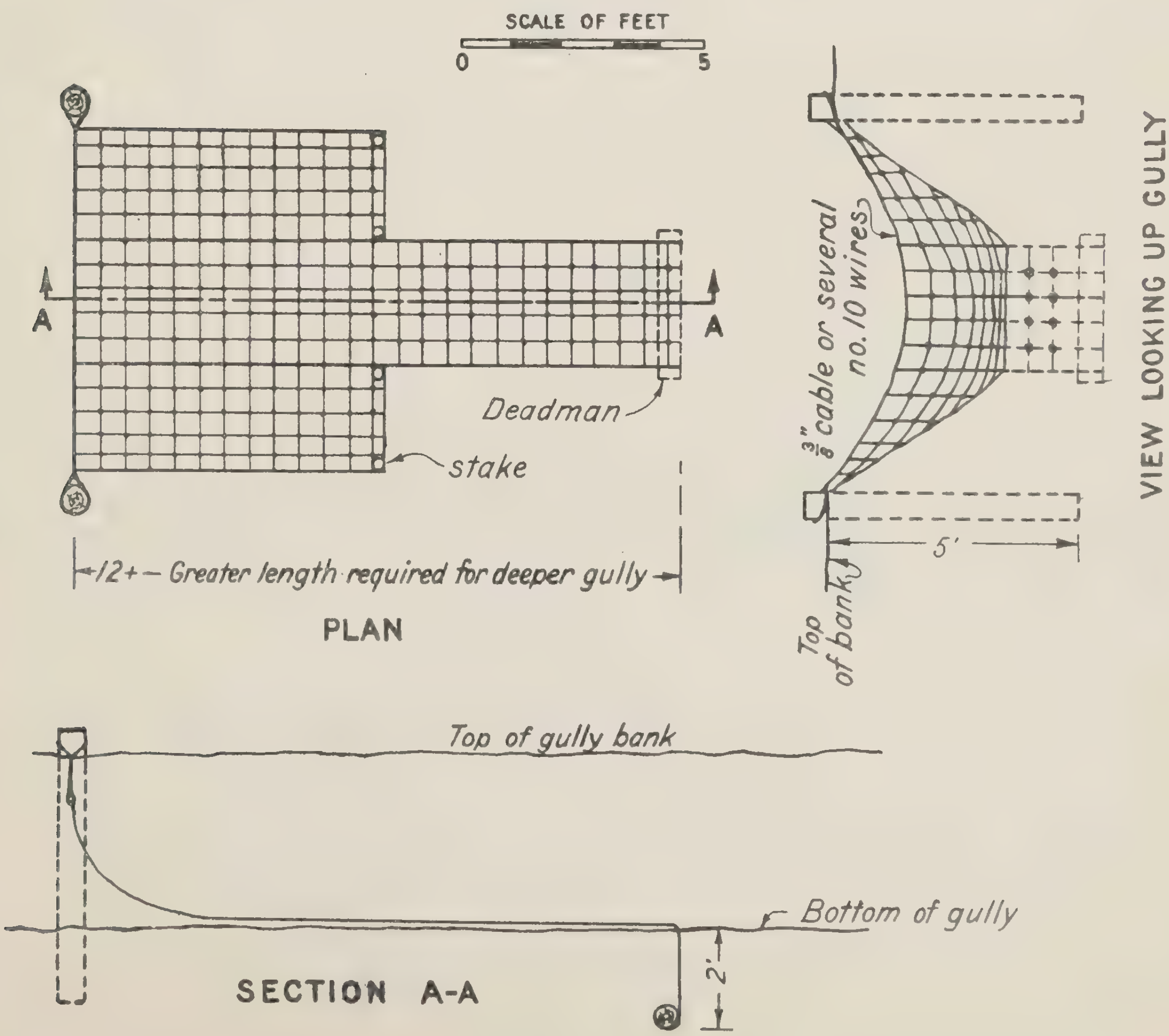

Fig. 6.– Cable and woven wire check dam for gully control

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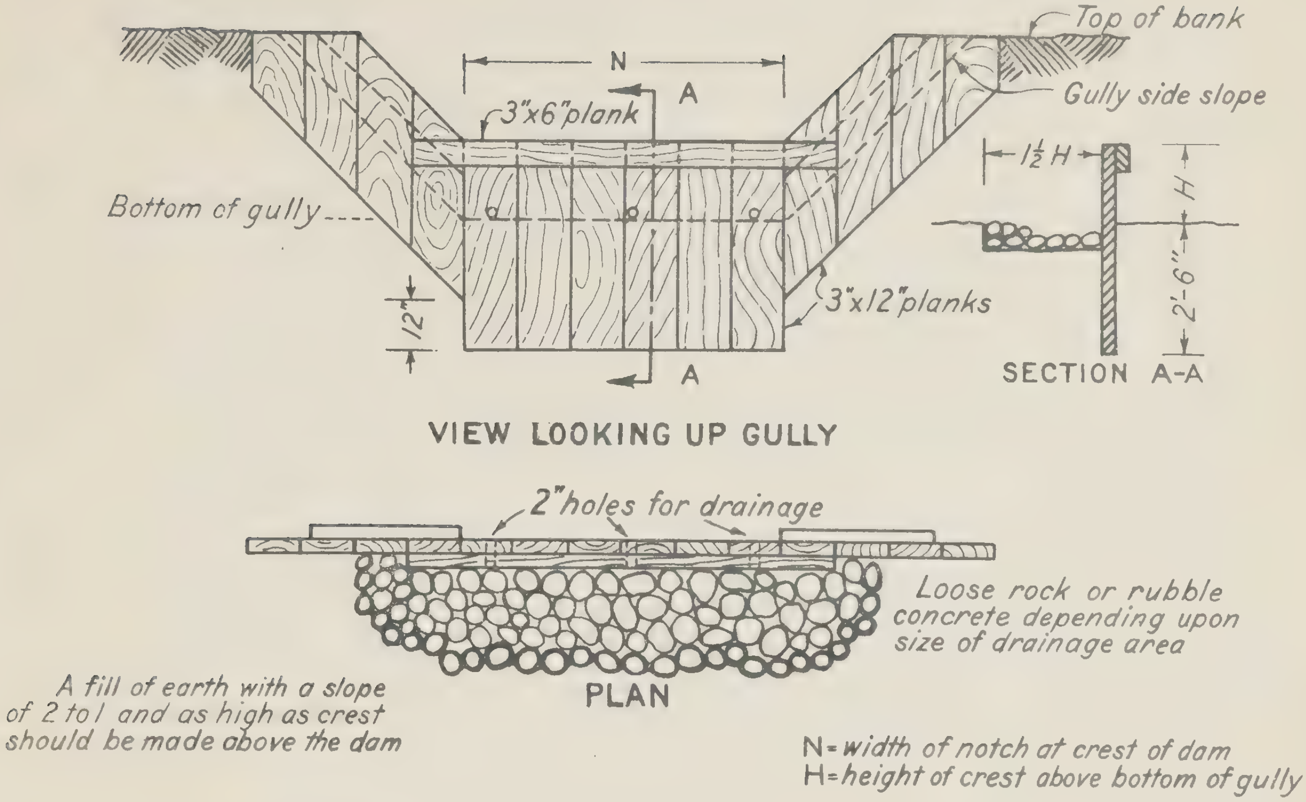
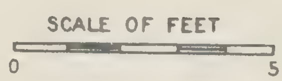


Fig. 7.– Plank check dam for gully control



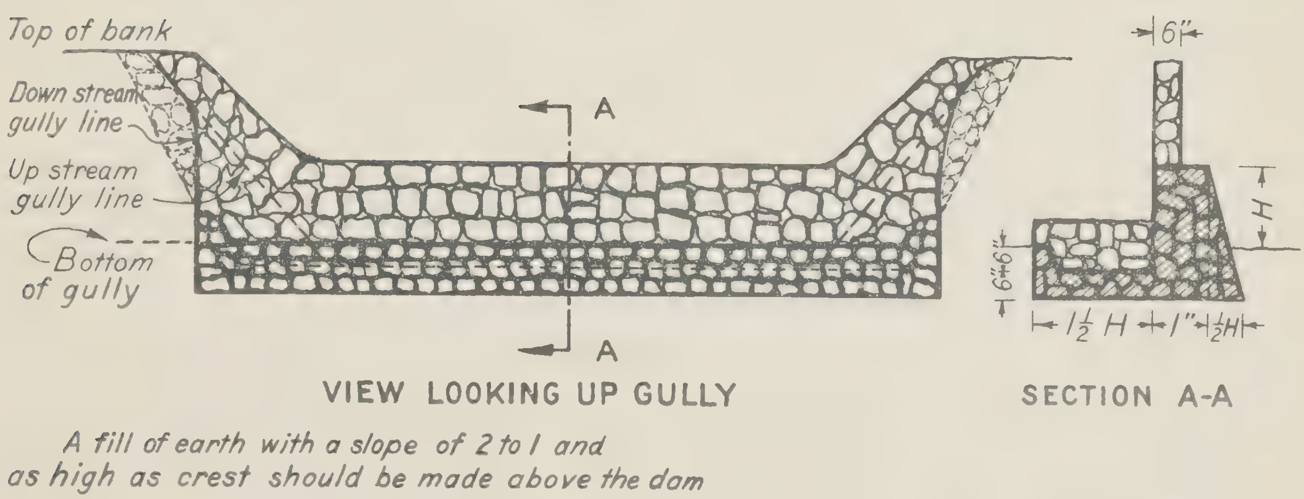


Fig. 8.– Rubble masonry check dam for gully control. Maximum height 4 to 5 feet

have comparatively large drainage areas with correspondingly large run-off, and for the design shown in the figure, is not recommended for a height of crest exceeding 5 feet.

Figure 9. In this figure is shown a loose rock check dam held in place by an envelope of woven wire completely enclosing the rock. It is difficult to build satisfactory loose rock dams without some means of holding the rock in place unless a large amount of rock is used and unless there is sufficient large rock for use on the surface to cover all small rock that could be easily moved by the current of water. Small rock can be quite effectively used in the construction of check dams when held in place with woven wire. The woven wire is laid on the bottom and sides of the gully, a piece being selected large enough to fold over the surface of the dam, and short pieces of wire spaced about 1 foot apart in both directions are attached to this bottom layer of woven wire. The rock is then placed to form the dam, as shown in the figure, permitting the short wires to extend through the rock. The woven wire is then folded over the surface of the entire dam including apron and side wall protection, and the short pieces of wire are drawn tight and fastened to the woven wire covering the entire surface of the dam. Careful workmanship is required to obtain a smooth looking job. This type of dam is recommended for a height not exceeding 5 to 6 feet.

SOIL SAVING DAMS

Soil-saving dams, as the name implies, are intended not only to control the extension and enlargement of a gully, but also to collect a deposit of soil and thereby reclaim an appreciable area for pasture or cultivable purposes. They are accordingly adapted especially for use on larger gullies where a considerable storage is created above the dam which both controls the run-off and thereby floods and tends to prevent deposit of silt in drainage channels and the resulting overflow of bottom lands. Under certain conditions they can be used more effectively than check dams in preventing the extension of the upper end of a large deep gully or the growth of incipient deep lateral gullies.

A good plan for restoring a large gully, particularly for pasture uses, is to install a soil-saving dam at the lower end, stop the extension of incipient lateral gullies and the upper end of the gully, plow in and smooth down the side slopes, and seed the slopes and bottom to pasture grasses or other vegetation. In order to promote the rapid growth of grass in the bottom, a line of drainage tile discharging into the vertical inlet culvert should be laid down the bottom of the gully. The vegetation in the gully tends to check the velocity of the water and to strain out particles of soil. The result is that the bottom of the gully acquires a steeper gradient and soil is deposited in the gully for a greater distance above the dam.

Soil-saving dams are of two types. In one type of run-off water is carried around or over the dam by spillways, and in the other it is carried through the dam by a pipe or culvert. Where the water is carried directly over the dam, it is usually built by masonry or concrete and where carried through the dam or around one end, it is usually built of earth. Combination earth and masonry soil-saving dams are often built. The center portion of the dam, where the spillway is located, is built of masonry or concrete and the wings or ends of the dam, of earth. All dams

requiring all or part masonry construction usually require special design and so will not be discussed in detail here. Where it is thought such a design is needed for a particular location it will be furnished upon request by the State engineer in charge of the erosion control work.

EARTH SOIL SAVING DAM

In the construction of an earth soil-saving dam it is important that the foundation for the dam be carefully prepared by clearing away all weeds, growth and debris, and plowing the ground to reduce the possibility of seepage along the bottom of the dam. Where the dam is 10 or more feet in height it is advisable to dig a trench the length of the dam, 4 to 6 feet wide and 1-1/2 feet deep. The sides of the trench should be made vertical so as to break the seam between the natural ground and the embankment. The embankment should be built in layers about 1 foot in depth. It is usually built with teams and scrapers, the material being compacted by the weight of the horses and implements; and the material should preferably be taken from the area above the dam below the proposed flood line if possible. The best results are obtained when the loose earth is sprinkled with water, which facilitates the compacting of the embankment and makes it more impervious. In figure 10 is a cross section of an earth dam, showing allowances to be made for settlement, side slopes of 2 to 1 and a top width of 4 feet.

The position of the culvert with vertical inlet through the dam is shown and other necessary dimensions are either given on the drawing or in the accompanying table. The vertical distance from the top of the dam to the top of the vertical inlet pipe varies from 4 to 5 1/2 feet and the horizontal distance from the top of the dam to the vertical inlet pipe from 9-1/2 to 16 feet for heights of dam at center varying from 10 to 25 feet. If the top of the inlet is placed too near (measured vertically) to the top of the dam, this may not permit sufficient head to insure the operation of the culvert and inlet to full capacity. Also, the flow through the culvert will be delayed in starting until after the level of the water has reached the top of the inlet, which would thereby increase the possibility of the run-off water from a long rain overflowing and washing out the earth embankment. The objection to placing the inlet pipe too close (measured horizontally) to the top of the dam is that accumulation of floating trash and debris near the dam has a tendency to clog the inlet or the protection to the inlet and greatly interferes with the water reaching the inlet. This may result in the water overtopping the dam. Prevention of the accumulation of trash around the inlet can be accomplished, to a certain extent, by a boom built of logs extending across the gully above the dam. The vertical extension wall on the side of the inlet pipe nearest the dam is to prevent the water's eddying around the pipe which may cause erosion and endanger the embankment. Such eddying reduces the rate of flow into the inlet pipe.

Attention is called to the curve at the junction of the vertical inlet and horizontal culvert. It is important that this junction be a smooth curve in order to reduce losses in head due to eddying with a corresponding reduction in the discharge through the culvert.

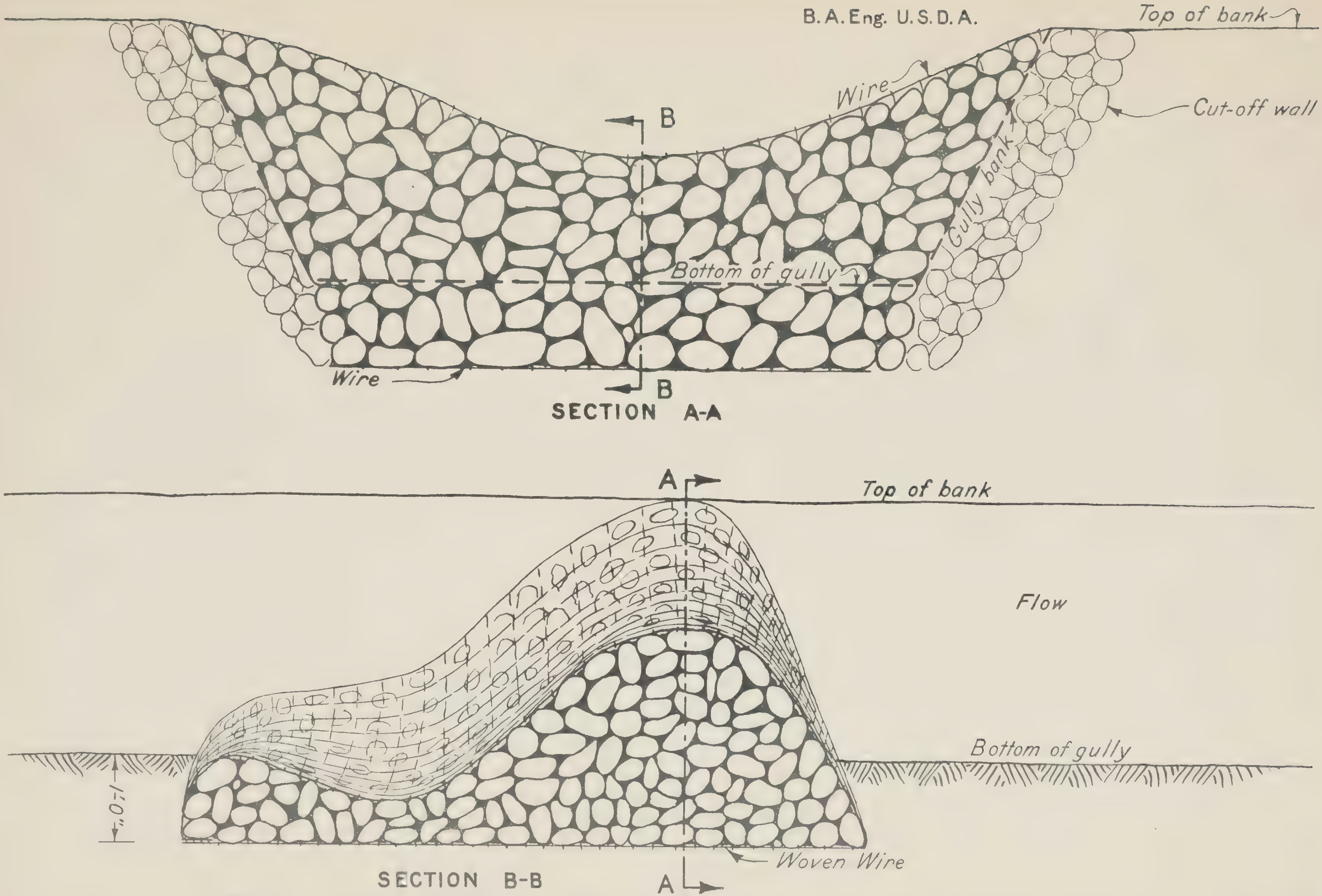


Fig. 9.—Loose rock check dam covered with woven wire

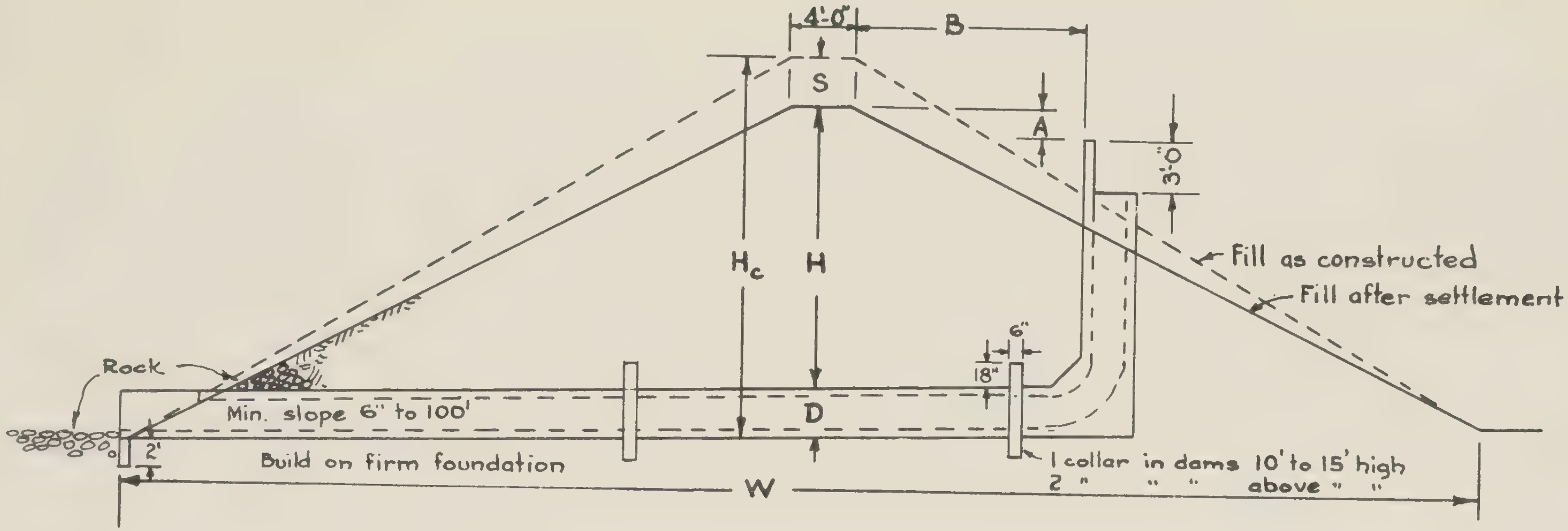


TABLE OF VARIABLES

H+D	Hc	S	A	B	W
10'-0"	11'-6"	1'-6"	1'-0"	9'-6"	44'-0"
15'-0"	17'-3"	2'-3"	1'-6"	12'-0"	64'-0"
20'-0"	23'-0"	3'-0"	2'-0"	14'-0"	84'-0"
25'-0"	29'-0"	4'-0"	2'-6"	16'-0"	104'-0"

U.S. DEPARTMENT OF AGRICULTURE
BUREAU OF AGRICULTURAL ENGINEERING
TYPICAL DESIGN OF SOIL SAVING DAMS
Based on University of Wisconsin experiments

Fig. 10

Collars are required around the horizontal culvert to prevent possible seepage along the outside wall, one collar being recommended for dams 10 to 15 feet high and two collars for greater heights. The culvert should be laid on firm soil and with a slope never less than 6 inches per 100 feet to insure satisfactory drainage. The invert of the culvert at the outlet end should be at the elevation of the bottom of the gully. For slopes no greater than 2 feet per 100 feet the profile of the bottom of the outlet end of the culvert should be as shown in the figure, and rock should be placed below the lower end of the spillway floor. For greater slopes, a specially designed outlet with depressed floor and a cross wall to reduce the energy by taking advantage of the hydraulic jump, should be used. Such a design depends upon the slope of floor, size of culvert, velocity, and discharge, and will be furnished upon request by the state engineer or may be prepared by the camp engineer and submitted to the state engineer for approval. Where it is desired to keep the fill drained above the dam and thus prevent the formation of a pond, drainage of the earth fill can be accomplished by means of a tile drain with outlet in the side wall of the vertical inlet pipe.

Details of the design of a reinforced concrete box culvert with vertical inlet for several different sizes of culverts and heights of dam are given in figures 11 to 13 and Table 1. Also vitrified pipe, concrete pipe, and corrugated pipe can be used for culverts where the cross-sectional area required is not exceeded by the area for maximum size of pipe manufactured. Curved pipe elbows should be used at the junction of the vertical inlet pipe and horizontal culvert pipe. Special instructions for laying corrugated pipe are given in the Handbook of Culvert and Drainage Practice, published by the Armco Company, Manufacturers' Association, Hamilton, Ohio.

HYDRAULICS OF EROSION CONTROL

The control of gullies is fundamentally a drainage problem. The proper design of the control structures requires an intimate knowledge of the science of hydraulics relating principally to the laws of run-off and the flow of water in open channels, weirs, spillways, and culverts. Run-off is the basis of the hydraulic design and must be determined for any particular watershed before it is possible to proceed with the design of the control structures. Hence, it is obvious that the success of a gully control project depends primarily upon the accurate determination of the run-off. Unless it is planned to store all of the run-off water from a watershed, the rate or intensity of the run-off is much more important than the amount, since the discharge capacity of spillways and culverts must be sufficient to take care of the high rates of run-off.

The rate of run-off from a drainage area or watershed depends principally upon the size and shape of the watershed, the slope of the land, the intensity and duration of the rainfall, the vegetative covering, the permeability of the soil, and the slope and condition of the drainage channels. The greatest rate of run-off will, of course, occur for rains of maximum intensity after the watershed is completely saturated. Two most accurate and satisfactory method of determining the rate of run-off for any particular watershed is to make a close study of all factors influencing run-off and then compute the probable rate of run-off for a rate of

rainfall of a given frequency. Rates of rainfall for periods of 5 minutes to about 1 hour are the ones that produce the highest rates of run-off from comparatively small and sloping watersheds such as are found on most erosion control projects. The frequency with which given rates of rainfall may probably occur play an important part in the design and the engineer must determine whether a structure should be designed to care for such rates of precipitation as occur once a year, once in 100 years, or some intermediate time interval.

The Rational Method of computing run-off is generally regarded as the most accurate in use since it makes provision for all factors affecting run-off. It is based upon the proposition that the maximum rate of run-off from any watershed area for a given intensity of rainfall occurs when all parts of the area are contributing to the flow. That part of the watershed nearest the outlet must still be contributing to the flow when the water from the most remote point on the watershed reaches the outlet. To fulfill this condition, the rain must continue as long as is required for the water to travel from the most remote point of the watershed to the lower end. This interval is called the time of concentration for the watershed. The maximum rate of run-off would therefore result from a rainfall of maximum uniform intensity continuing for a time equal to or exceeding the time of concentration. The following formula is used in computing the rate of run-off by the Rational Method:

$$Q = C\ I\ A$$

Where Q = Rate of run-off in cubic feet per second

C = Run-off coefficient or coefficient of imperviousness, representing the ratio of the rate of run-off to the rate of rainfall.

I = Rainfall intensity in cubic feet per second per acre, or approximately in inches per hour.

A = The watershed area in acres.

A complete discussion of the Rational Method, giving experimental results and examples showing its practical application, is given in a reprint from the Journal of Agricultural Research, Vol. 34, No. 9, entitled "Run-off from Small Agricultural Areas." A study of this article should enable the engineer to determine the rate of run-off to be used in the design of erosion control structures with a considerable degree of precision for any particular watershed.

In order to facilitate the work of determining the proper rate of run-off to be used for any particular watershed, three sets of curves have been prepared, giving rates of run-off in cubic feet per second for watersheds of different sizes and with different characteristics. The curves given in figure 14 are for watershed areas up to 30 acres and for rainfall intensities with probable frequency of once in 10 years. The other two sets of curves in figures 15 and 16 are for watershed areas ranging from 30 to 1,000 acres and for probable rainfall frequencies of once in 10 years and once in 50 years respectively. Structures that would not be materially damaged by the capacity of the waterway being exceeded, should be designed to take care of such rains as occur once in 10 years and, where damage of a serious nature, or large financial loss would result from the capacity of the waterway being exceeded, should be designed for a probable rainfall frequency of once in 50 years.

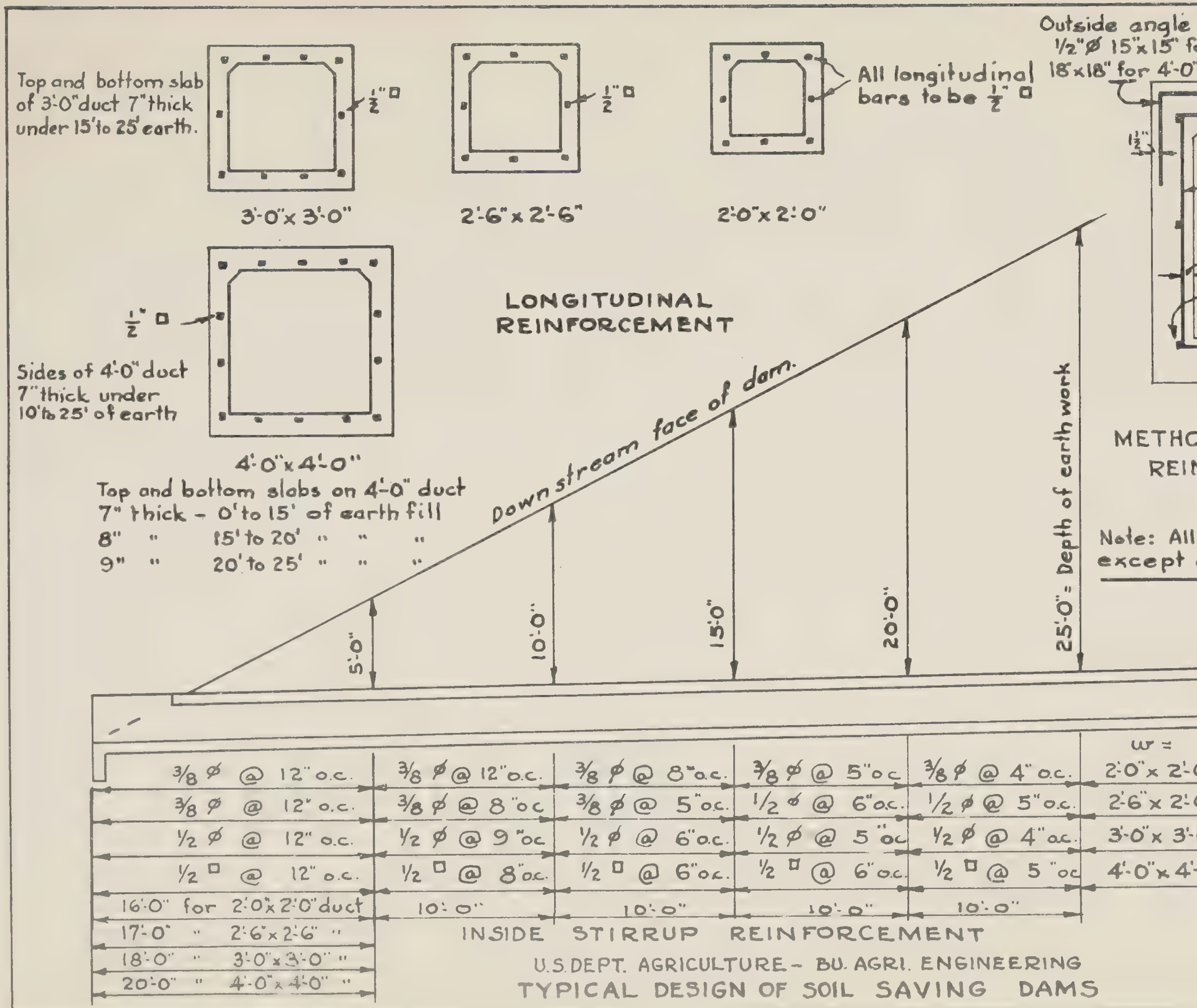
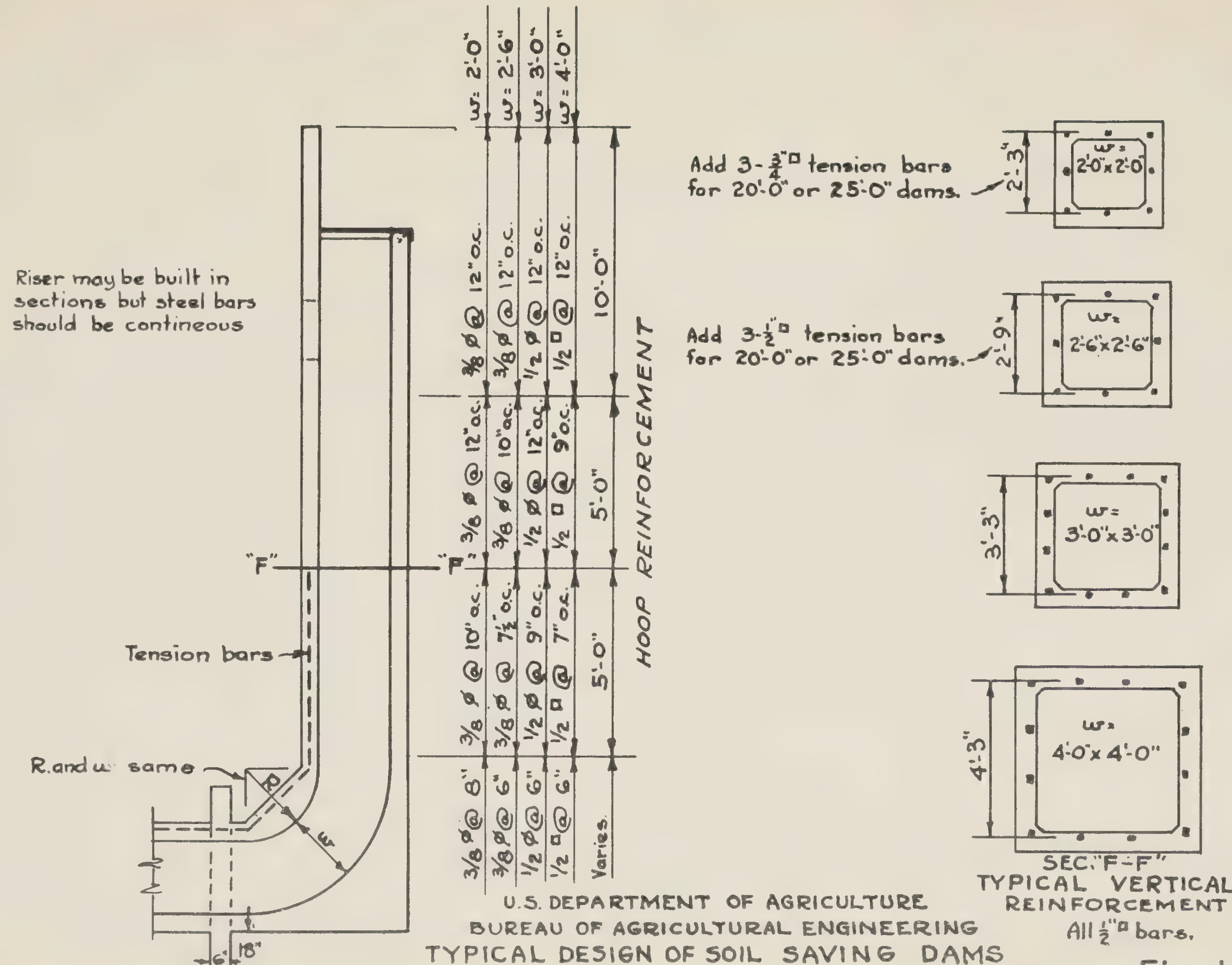

Top and bottom slab of 3'-0" duct 7" thick under 15' to 25' earth.
1/2" □
3'-0" x 3'-0"
1/2" □
2'-6" x 2'-6"
All longitudinal bars to be 1/2" □
2'-0" x 2'-0"
Outside angle reinforcement to be 1/2" ⌀ 15" x 15" for 3'-0" duct and 1/2" □ 18" x 18" for 4'-0" duct.- 12" o.c for both.
1 1/2"
Inside Stirrups
1 1/2"
Longitudinal bars
METHOD OF PLACING REINFORCEMENT
Note: All concrete 6" thick except as noted.
1/2" □
Sides of 4'-0" duct 7" thick under 10' to 25' of earth
4'-0" x 4'-0"
LONGITUDINAL REINFORCEMENT
Top and bottom slabs on 4'-0" duct
7" thick - 0' to 15' of earth fill
8" " 15' to 20' " " "
9" " 20' to 25' " " "
Down stream face of dam.
5'-0"
10'-0"
15'-0"
20'-0"
25'-0" = Depth of earth work
w =
3/8 ⌀ @ 12" o.c. | 3/8 ⌀ @ 12" o.c. | 3/8 ⌀ @ 8" o.c. | 3/8 ⌀ @ 5" o.c. | 3/8 ⌀ @ 4" o.c. | 2'-0" x 2'-0" duct
3/8 ⌀ @ 12" o.c. | 3/8 ⌀ @ 8" o.c. | 3/8 ⌀ @ 5" o.c. | 1/2 ⌀ @ 6" o.c. | 1/2 ⌀ @ 5" o.c. | 2'-6" x 2'-6" "
1/2 ⌀ @ 12" o.c. | 1/2 ⌀ @ 9" o.c. | 1/2 ⌀ @ 6" o.c. | 1/2 ⌀ @ 5" o.c. | 1/2 ⌀ @ 4" o.c. | 3'-0" x 3'-0" "
1/2 □ @ 12" o.c. | 1/2 □ @ 8" o.c. | 1/2 □ @ 6" o.c. | 1/2 □ @ 6" o.c. | 1/2 □ @ 5" o.c. | 4'-0" x 4'-0" "
16'-0" for 2'-0" x 2'-0" duct | 10'-0" | 10'-0" | 10'-0" | 10'-0"
17'-0" " 2'-6" x 2'-6" "
18'-0" " 3'-0" x 3'-0" "
20'-0" " 4'-0" x 4'-0" "
INSIDE STIRRUP REINFORCEMENT
U.S. DEPT. AGRICULTURE - BU. AGRI. ENGINEERING
TYPICAL DESIGN OF SOIL SAVING DAMS

Fig. 11



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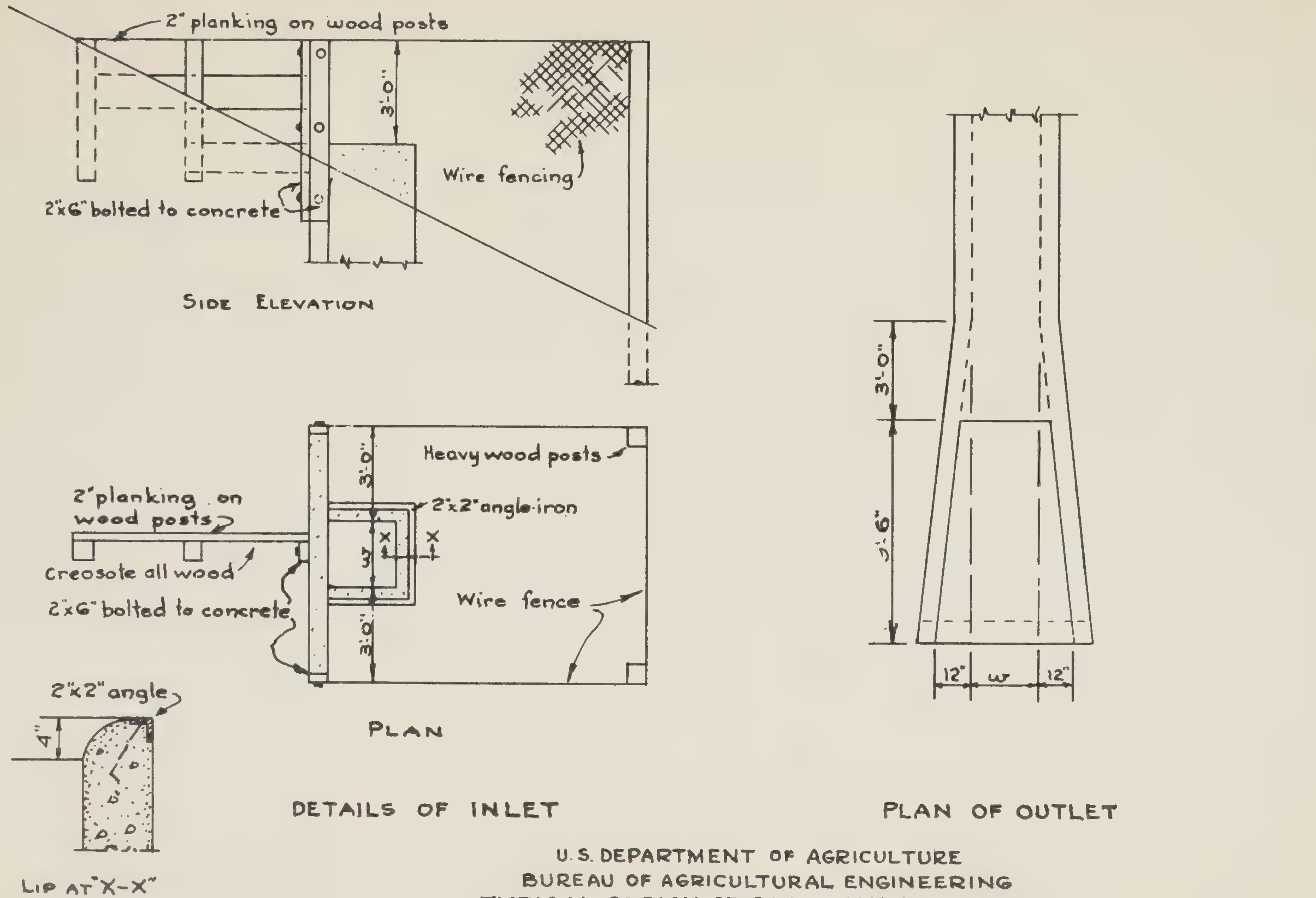
BUREAU OF AGRICULTURAL ENGINEERING
TYPICAL DESIGN OF SOIL SAVING DAMS

Fig. 12



U.S. DEPARTMENT OF AGRICULTURE
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TYPICAL DESIGN OF SOIL SAVING DAMS

Fig. 13

U.S. DEPARTMENT OF AGRICULTURE
BUREAU OF AGRICULTURAL ENGINEERING

TYPICAL DESIGN OF SOIL SAVING DAMS

BILL OF MATERIALS

FACTORS		CONCRETE MIX 1:2:4			REINFORCEMENT LIN. FEET			
Height dam H+D=	Size of duct w=	CEMENT Bags.	SAND Cu. Yd.	STONE Cu. Yd	3/8" ⌀	1/2" ⌀	1/2" □	3/4" □
10'-0"	2'-0"	60	5	10	640		450	
"	2'-6"	66	5.5	11	830		460	
"	3'-0"	78	6.5	13		1000	660	
"	4'-0"	112	9.5	19			1730	
15'-0"	2'-0"	76	6.5	13	910		570	
"	2'-6"	93	7.5	15	1290		590	
"	3'-0"	110	9.5	19		1400	870	
"	4'-0"	146	12.5	25			3020	
20'-0"	2'-0"	93	8	16	1400		700	3pc. 14'-0"
"	2'-6"	117	10	20	1400	320	750	
"	3'-0"	139	12	24		2170	1100	
"	4'-0"	186	15.5	31			3550	
25'-0"	2'-0"	111	9.5	19	2000		820	3pc. 14'-0"
"	2'-6"	141	12	24	1960	710	880	
"	3'-0"	178	14.5	29		3430	1240	
"	4'-0"	222	18.5	37			4580	

Table 1

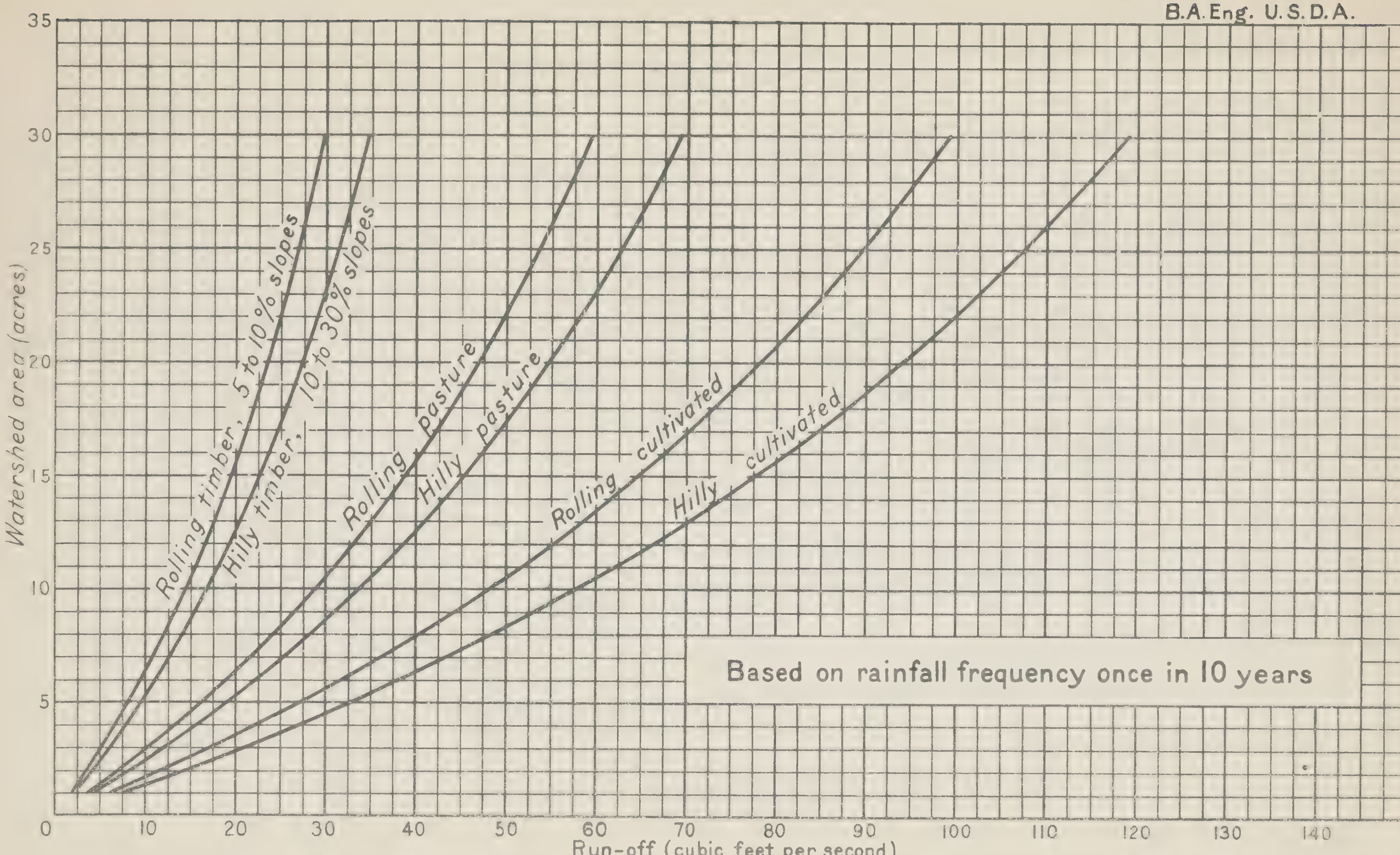

Fig. 14.—Rates of run-off from timber, pasture, and cultivated watersheds for area group no. 3 shown in Fig. 17

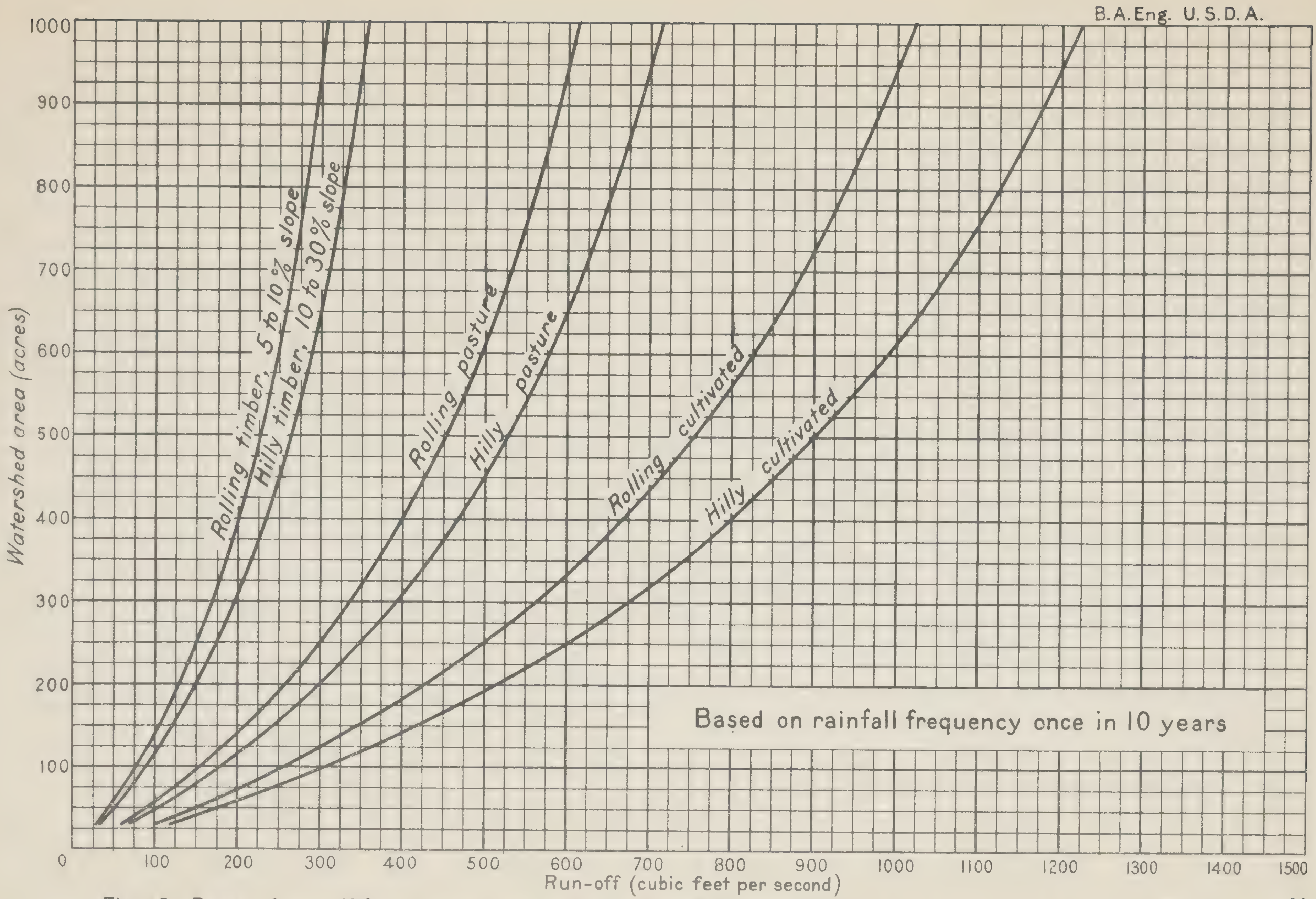

Fig. 15.- Rates of run-off from timber, pasture, and cultivated watersheds for area group no. 3 shown in Fig. 17

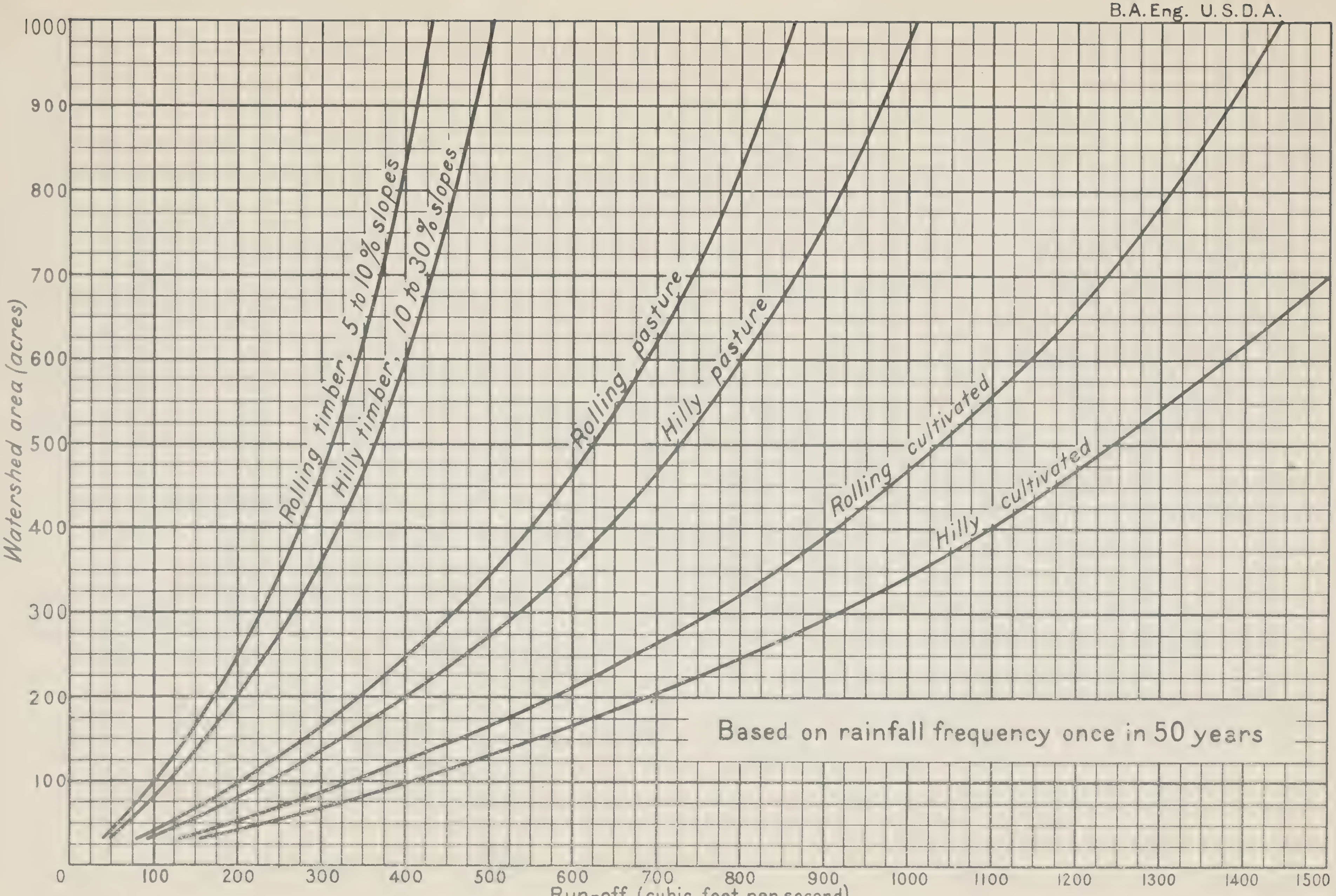

Fig. 16.- Rates of run-off from timber, pasture, and cultivated watersheds for area group no. 3 shown in Fig. 17

Values of C used in making computations by the Rational Method are as follows for the different types of watersheds: - Cultivated rolling, 0.6; cultivated hilly, 0.72; pasture rolling, 0.36; pasture hilly, 0.42; timber rolling, 0.18; timber hilly, 0.21. By "rolling" is meant land with slopes of 5 to 10 percent and by "hilly", slopes of 10 to 30 percent. Other values for C may be used where conditions on watershed warrant and the ratio of the value chosen to the above values, times the rate of run-off given by the curve, will give the rate of run-off for the new value selected for C.

Rainfall intensities used in computing the values for the curves in figures 14, 15, and 16, are for the area marked group No. 3 on the map in figure 17 taken from Meyers Hydrology. In order to determine rates of run-off for the other areas represented by groups shown in this figure, it is necessary to determine the ratio of the rainfall intensities in these groups to those in group No. 3. These ratios are given in Table No. 2 for the various groups for rainfall frequencies of once in 10 and once in 50 years. For example, to determine the rate of run-off from 100 acres of cultivated rolling land in group No. 2, the rate is first determined for group 3 from figure 15. This is found to be 260 second feet. The ratio of the rainfall intensity for group 2 to that of group 3 for 100 acres is 1.19. Multiplying 260 second feet by 1.19, the result, 309 second feet is obtained, which is the rate of run-off to use for 100 acres in the area marked group No. 2 in figure 17.

WATERSHED

A reconnaissance survey should be made of the watershed to determine whether it should be classified as rolling or hilly, to determine approximate acreage of cultivated, pasture, and timber lands, and to determine the size of the watershed area in acres. The growing tendency is to place more land in pasture or timber so that ordinarily it would be safe to assume that the proportion of pasture and timber area would not be reduced. However, if definite information is available that it is the intention to clear for cultivation, pasture or timber land, then proper consideration should be given this matter in classifying the lands of the watershed.

The area of the watershed can often be closely determined from the location of land lines and pacing any distances required. Where this is not possible, the area can be determined approximately by a compass traverse, using the pacing method to determine distances. This traverse survey should then be plotted with a protractor and area computed or determined with a planimeter. Where a transit is available, a quick stadia traverse survey can be made or, for a small watershed, the bearing and distance to points on the boundaries of the watershed area can quickly be determined from one location of the transit.

FLOW OF WATER THROUGH OR OVER EROSION CONTROL DAMS

Check Dams

Water flowing down a gully may pass over or through an erosion control dam. Small dams of limited height, usually known as check dams, in small gullies have notches in the center to permit the run-off water to pass through without damage to the structure. These notches resemble weirs of the broad crested type and the discharge capacity of the notches can be computed by the formula:

$$Q = 3.39 \ L \ H^{\frac{3}{2}}$$

Where Q = discharge in cubic feet per second
L = length of weir or notch in feet
and H = depth of weir notch or head on crest of weir in feet.

Provision is not made in this formula for the velocity of approach in the channel which is on the side of safety.

In Table No. 3 is given the discharge capacity in cubic feet per second for weir notches in erosion check dams, computed by the foregoing formula. In order to facilitate reference to this table, the following example is given:

It is required to determine the size of a notch in an erosion check dam for a gully 5 feet deep and 5 feet wide, having a drainage area of 12 acres of cultivated rolling watershed. Since exceeding the discharge capacity of a notch in a check dam would not be serious, the size of the notch is made sufficient to provide for a rainfall intensity having a frequency of once in 10 years.

Referring to figure 14, it is seen that a run-off of 55.3 cubic feet per second is given for a rolling, cultivated watershed area of 12 acres. Using this discharge and entering Table No. 3, it is found that a notch 6 feet long and 2 feet deep has a discharge capacity of 57.6 cubic feet per second. Since the gully is only 5 feet wide, a shorter notch with the required discharge capacity must be selected. A notch 4 feet long and 2.5 feet deep will take care of a discharge of 53.6 cubic feet per second, which is approximately equivalent to the rate of run-off from the watershed and has satisfactory dimensions for the particular gully.

SOIL SAVING DAMS WITH LARGE SPILLWAYS

Soil-saving dams with spillways are used for controlling larger gullies than are usually controlled by check dams with notches, and therefore require larger openings for the flow of water. Usually the crests of such dams are much broader than for notch check dams and the formula for computing the flow over broad crested spillways is slightly different from that for computing the flow through the notches of the smaller check dams. The discharges in cubic feet per second for flow over spillways is

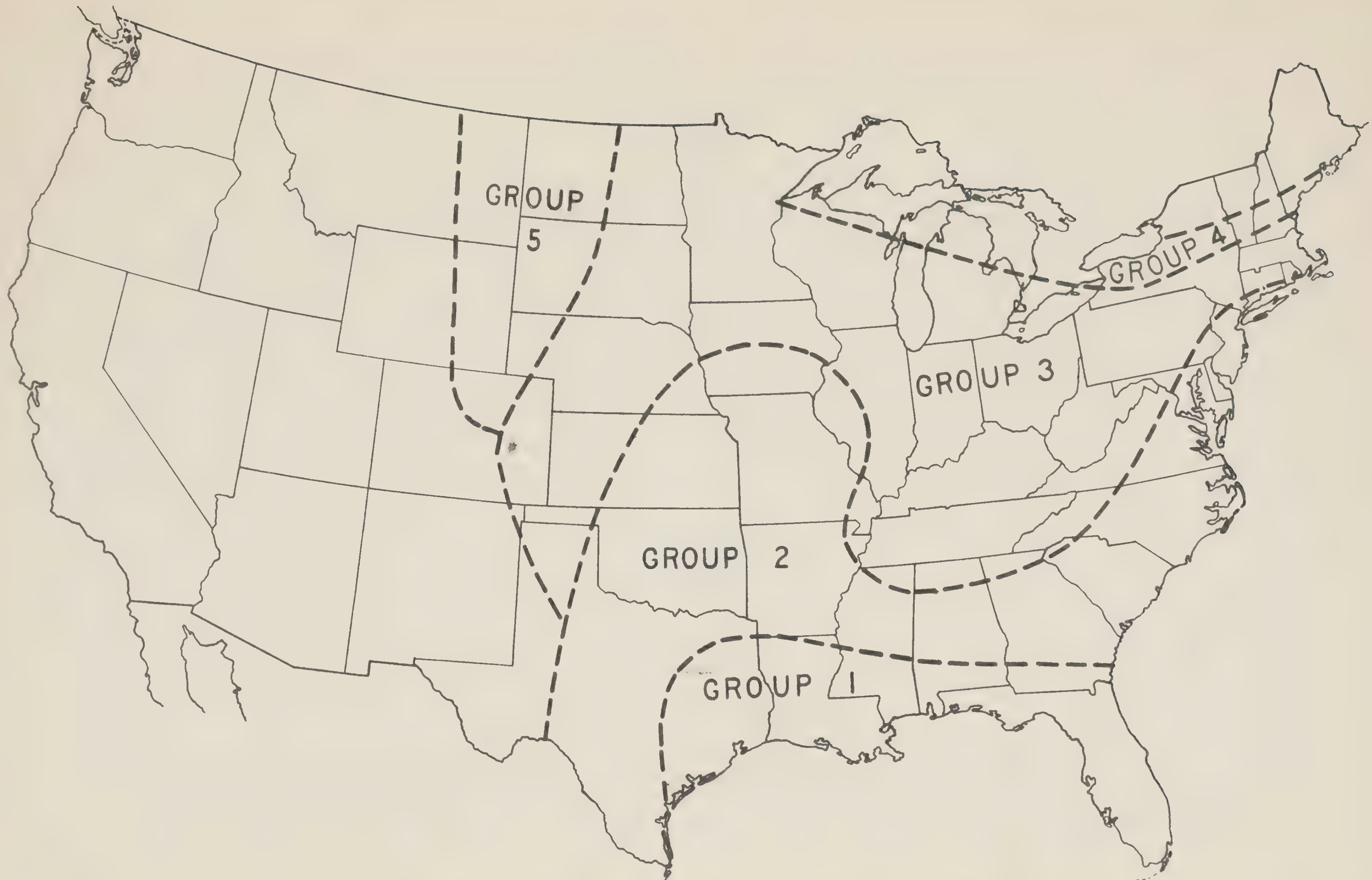

Fig. 17.– Boundaries of areas of similar rainfall intensities for short periods. *(From Meyer's Hydrology)*

TABLE 2

RATIOS OF RAINFALL INTENSITIES IN
GROUP NO. 3 TO THOSE IN GROUPS GIVEN BELOW

Area in acres	Rainfall frequency = once in 10 years				Once in 50 years			
	Group to which ratios apply							
	Group 1	Group 2	Group 4	Group 5	Group 1	Group 2	Group 4	Group 5
1	1.15	1.08	0.90	1.02	1.02	1.06	0.95	0.97
10	1.22	1.12	0.90	0.97	1.07	1.08	0.94	0.94
50	1.29	1.16	0.89	0.89	1.14	1.11	0.92	0.90
100	1.34	1.19	0.89	0.86	1.20	1.13	0.91	0.87
200	1.42	1.23	0.89	0.83	1.30	1.15	0.89	0.83
400	1.50	1.27	0.89	0.80	1.42	1.18	0.89	0.80
600	1.55	1.30	0.88	0.78	1.49	1.21	0.89	0.78
800	1.58	1.32	0.88	0.76	1.56	1.23	0.88	0.77
1000	1.62	1.33	0.88	0.75	1.61	1.24	0.88	0.76

Taken from Table 15, Meyer's Elements of Hydrology, first edition
See Figure 17 for location of areas of groups given in Table

TABLE 3

DISCHARGE IN CUBIC FEET PER SECOND FOR WEIR NOTCHES IN EROSION CHECK DAMS

Depth of Weir	Length of weir notches in feet														
Notch	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Feet															
0.5	1.2	2.4	3.6	4.8	6.0	7.2	8.4	9.6	10.8	12.0	13.2	14.4	15.6	16.8	18.0
1.0	3.4	6.8	10.2	13.6	17.0	20.3	23.7	27.1	30.5	33.9	37.3	40.7	44.1	47.5	50.9
1.5	6.2	12.5	18.7	24.9	31.1	37.4	43.6	49.8	56.0	62.3	68.5	74.7	81.0	87.2	93.4
2.0	9.6	19.2	28.8	38.3	47.9	57.5	67.1	76.7	86.3	95.9	105.5	115.0	124.6	134.2	143.8
2.5	13.4	26.8	40.2	53.6	67.0	80.4	93.8	107.2	120.6	134.0	147.4	160.8	174.2	187.6	201.0
3.0	17.6	35.2	52.8	70.5	88.1	105.7	123.3	140.9	158.5	176.1	193.8	211.4	229.0	246.6	264.2
3.5	22.2	44.4	66.6	88.8	111.0	133.2	155.4	177.6	199.8	222.0	244.2	266.4	288.6	310.8	333.0
4.0	27.1	54.2	81.4	108.5	135.6	162.7	189.8	217.0	244.1	271.2	298.3	325.4	352.6	379.7	406.8
4.5	32.4	64.7	97.1	129.4	161.8	194.2	226.5	258.9	291.2	323.6	356.0	388.3	420.7	453.1	485.4
5.0	37.9	75.8	113.7	151.6	189.5	227.4	265.3	303.2	341.1	379.0	416.9	454.8	492.7	530.6	568.5

The above values are computed by formula $Q = 3.39\ L.\ H^{3/2}$

Where Q = discharge in cubic feet per second

L = length of weir notch in feet

H = depth of weir notch in feet

given in Table 4 for spillways with depths of 1/2 to 8 feet, and lengths of 2 to 30 feet and are computed from the following formula:

$$Q = 3.2\ L\ H^{\frac{3}{2}}$$

Where Q = discharge in cubic feet per second
L = length of spillway in feet
H = head on crest in feet.

No account is taken of the velocity of approach in the formula which is on the side of safety. This table of spillway capacities is also for use in determining the discharge over spillways around one end of an ordinary earth soil-saving dam with no other outlet, or in the determination of the flow over emergency spillways used in connection with drop inlet earth soil-saving dams which it is advisable to provide where conditions permit. Since a spillway used in connection with a drop inlet culvert will seldom be needed except during rains of rare occurrence, a sodded surface for the spillway will be satisfactory but it should be carefully examined after water flows over and any damage done by erosion should be immediately repaired. Spillways built of permanent material are required where no other provision is made to remove the run-off water. Also oftentimes the size and thereby the cost of a drop inlet culvert can be greatly reduced by providing for part of the run-off in a spillway around the end of the dam. For spillways of unusual shaped crests, the reader is referred to King's Handbook on Hydraulics for the selection of the proper coefficient to use in the foregoing formula. Whether the rate of run-off to be used in determining the size of the spillway should be chosen from figure 15 or 16 for an intensity of rainfall with a frequency of once in 10 years or once in 50 years depends upon whether a failure of the structure would be of a serious nature or result in a large financial loss.

DROP INLET CULVERT SOIL SAVING DAMS

In figures 18 and 19 are given the discharge capacities for pipe and box culverts of various sizes for heads ranging from 5 to 25 feet. The discharge capacities of the culverts are computed from the following formula:

$$H = \frac{V^2}{2g} + \left(\frac{1}{c^2} - 1\right)\frac{V^2}{2g} + f_1 \frac{LV^2}{D2g} + f_2 \frac{V^2}{2g}$$

in which the sum of the velocity head, and the loss of head at entrance, the loss due to friction in the pipe, and the loss at the bend, are equivalent to the total static head represented by the vertical distance from the surface of the water above the dam (1 foot lower than the top of the dam) to the inside of the pipe at the top of the outlet end of the culvert. Transposing the equation, the following is obtained:

$$Q = aV = a\sqrt{\frac{2gH}{1+\left(\frac{1}{C^2}-1\right)+f_1\frac{L}{D}+f_2}}$$

Where Q = discharge in cubic feet per second
a = area of the pipe or box in square feet
V = velocity in feet per second
H = total static head in feet, as explained above
L = length of pipe in feet
D = diameter of pipe in feet
g = acceleration due to gravity
C = entrance less coefficient. Values for this coefficient were taken from figure 84 in Schroder and Dawson's Hydraulics, 1927.
f_1 = loss of head due to friction in pipe. Values for this coefficient, based on fairly smooth pipe, were taken from figure 107 in Schroder and Dawson's Hydraulics, 1927.
f_2 = loss of head at bend. Values for this coefficient, based on cast iron pipe, were taken from Table 80 in King's Handbook of Hydraulics, Second Edition.

If it is anticipated that the outlet end of the culvert will be submerged, the probable elevation of the surface of the water at the end should be determined, and the difference in the elevation of the water surface above and below the dam should be used as the total static or effective head on the culvert.

The computations are based upon the drop inlet culvert design and installation shown in figure 10 and are not directly applicable to other methods of installation where the length of pipe, curvature at bend, and entrance conditions are different. In figure 12 are shown details of the curvature at the bend and in figure 13 are shown details of the rounded lip entrance to culvert. Concrete should be used in bell-mouthed pipes to secure the rounded effect shown in figure 13. While the friction factors used in the formula are for fairly smooth pipe, the results are sufficiently accurate for all practical purposes in determining the discharge for concrete and vitrified pipe.

For corrugated pipe the discharge capacities, as given in the table, should be reduced. Experiments on vitrified pipe with straight end wall, bell-mouthed entrance, and corrugated pipe with straight end wall entrance for a head of 5 feet indicate that the ratio of the discharge of these two pipes are as given in Table 5. In determining the discharge capacity of a corrugated pipe, it is recommended that the discharge be first determined from the curves, figures 18 and 19, and then this discharge be multiplied by the ratios given in Table 5 to obtain the discharge of a corrugated pipe. This procedure will give slightly less than the actual capacity of the corrugated pipe on the assumption that the loss in head in both pipes at the bend will be the same.

TABLE 4

APPROXIMATE DISCHARGE CAPACITY IN CUBIC FEET PER SECOND OF BROAD CRESTED SPILLWAYS FOR USE WITH EARTH SOIL SAVING DAMS AND LARGE MASONRY DAMS

Head on crest of spillway	Length of spillway in feet														
	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30
Feet	2.3	4.5	6.8	9.1	11.3	13.6	15.8	18.1	20.4	22.6	24.9	27.2	29.4	31.7	33.9
0.5	6.4	12.8	19.2	25.6	32.0	38.4	44.8	51.2	57.6	64.0	70.4	76.8	83.2	89.6	96.0
1.5	11.8	23.5	35.2	47.0	58.8	70.5	82.3	94.1	105.8	117.6	129.3	141.1	152.8	164.6	176.4
2.0	1[illegible].1	36.2	54.3	72.4	90.5	108.6	126.7	144.8	162.9	181.0	199.1	217.2	235.3	253.4	271.5
2.5	25.3	50.6	75.9	101.2	126.5	151.8	177.1	202.4	227.7	233.0	278.3	303.6	328.9	354.2	379.5
3.0	33.3	66.5	99.8	133.0	166.3	199.5	232.8	266.0	299.3	332.5	365.8	399.1	432.3	465.6	498.8
3.5	41.9	83.8	125.7	167.6	209.5	251.4	293.4	335.3	377.2	419.1	461.0	502.9	544.8	586.7	628.6
4.0	51.2	102.4	153.6	204.8	256.0	307.2	358.4	409.6	460.8	512.0	563.2	614.4	665.6	716.8	768.0
4.5	61.1	122.2	133.3	244.4	305.5	366.6	427.7	488.8	549.8	610.9	672.0	733.1	794.2	855.3	916.4
5.0	71.6	143.1	214.7	286.2	357.8	429.3	500.9	572.4	644.0	715.5	787.1	858.6	930.2	1001.7	1073.3
5.5	82.6	165.1	247.7	330.2	412.8	495.4	577.9	660.5	743.0	825.6	908.2	990.7	1073.3	1155.8	1238.4
6.0	94.1	188.2	282.2	376.3	470.4	564.5	658.6	752.6	846.7	940.8	1034.9	1129.0	1223.0	1317.1	1411.2
6.5	106.0	212.1	318.1	424.2	530.2	636.3	742.3	848.4	954.4	1060.5	1166.5	1272.6	1378.6	1484.7	1590.7
7.0	118.5	237.1	355.6	474.1	592.6	711.2	829.7	948.2	1066.8	1135.3	1303.8	1422.3	1540.9	1659.4	1777.9
7.5	131.5	262.9	394.4	525.8	657.3	788.7	920.2	1051.6	1183.1	1314.6	1446.0	1577.5	1708.9	1840.4	1971.3
8.0	144.8	289.7	434.5	579.3	724.2	869.0	1013.8	1158.7	1303.5	1448.3	1593.2	1738.0	1882.8	2027.6	2172.5

Computed by formula $Q = 3.2\ L\ H^{3/2}$

Where Q = discharge in cubic feet per second

L = length of spillway in feet

H = head of water on crest of spillway in feet

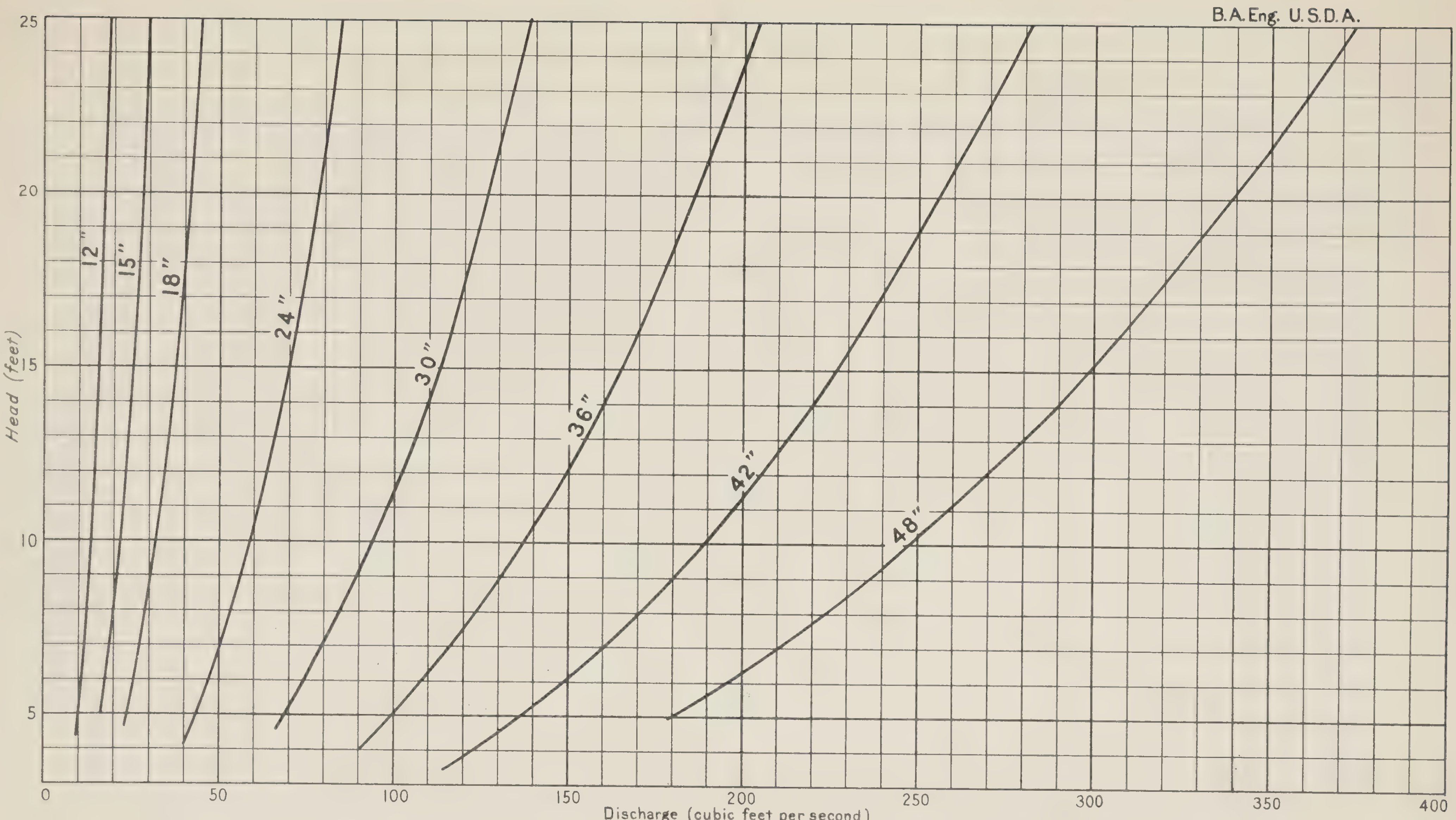

Fig. 18.- Discharge capacilies of drop-inlet pipe culverts for installation as shown in Fig. 10

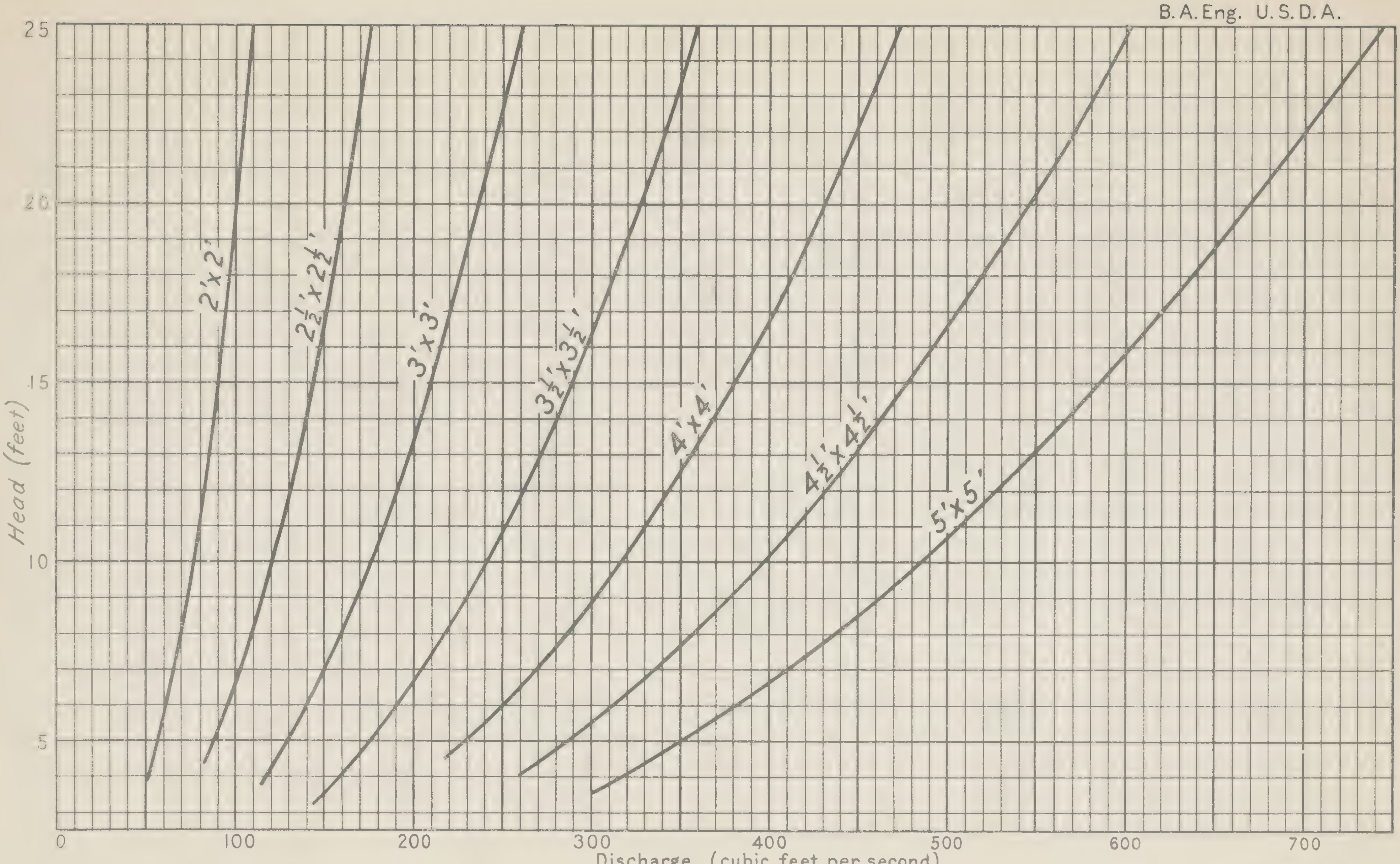

Fig. 19.- Discharge capacities of drop-inlet box culverts for installation as shown in Fig. 10

TABLE 5

RATIO OF THE DISCHARGE CAPACITIES OF CORRUGATED PIPE TO VITRIFIED PIPE

Size of pipe	Length = 100 feet, Head = 5 " — Discharge in cubic ft. per sec.			Length = 200 feet, Head = 5 " — Discharge in cubic ft. per sec.		
	Corrugated pipe	Vitrified pipe	Ratio of discharges	Corrugated pipe	Vitrified pipe	Ratio of discharges
12	4.12	7.85	.525	2.98	6.04	.493
15	7.23	13.20	.548	5.29	10.30	.514
18	11.40	20.00	.570	8.42	15.90	.530
24	23.30	33.10	.612	17.40	31.10	.559
30	40.30	62.10	.649	30.50	51.80	.589
36	62.30	91.50	.681	47.90	77.80	.616
48	123.00	165.00	.745	97.20	145.00	.670

Note - The discharge capacities in cubic feet per second are taken from Tables 15 and 16 of Bulletin I, "The Flow of Water Through Culverts," Studies in Engineering, University of Iowa. Table 15 gives capacities of vitrified clay pipe culverts, straight end-wall entrance, bell end upstream, and Table 16 gives capacities of corrugated metal pipe culverts, straight end-wall entrance.

EXAMPLE ILLUSTRATING METHOD OF USING CURVES AND TABLES

It is desired to determine the size of a drop inlet culvert in the State of Indiana to be built in connection with an earth soil-saving dam and to operate under a head of 20 feet. The drainage area of the gully above the proposed location for the dam is a rolling watershed of 150 acres, 50 acres of which is in timber, 50 acres in pasture, and 50 acres in cultivation. At one end of the dam a sodded depression in the ground surface exists which is 3 feet lower than the proposed top of the dam and about 20 feet wide which can be used to serve as a spillway discharging into the gully below the dam.

First it is necessary to determine the rate of run-off for the watershed for use in determining the size of the culverts. Since the State of Indiana lies in that section of the United States marked Group 3 on the map in figure 17 for which the run-off curves apply, it will not be necessary to make any correction in rate of run-off as determined from the curves. Since the failure of so high a structure would result in considerable damage, it is believed desirable that provision be made to take care of such rains as occur once in 50 years. Referring to figure 16 which gives rates of run-off for rainfall frequency of once in 50 years, the rate of run-off in cubic feet per second for 150 acres, as determined from the curve marked "rolling timber," is 140; from the curve marked "rolling pasture" is 280; and for the curve marked "rolling cultivated" is 460. Since there are only 50 acres of each type of land instead of 150, all of the above values should be divided by 3 and then added together which makes a total of 293 cubic feet per second or the probable rate of run-off for the total watershed. In the foregoing proceeding it is necessary that the watershed be considered as a unit regardless of differences in cover. It would not be correct to take the rates of run-off for 50 acres from the curve for the three different vegetative conditions on the watershed as the rates of run-off from three small 50-acre watersheds would be much higher than the rate from one large 150-acre watershed and the total rate of run-off obtained would be too high.

Part of the run-off can be removed by a spillway having effective dimensions, say of about 16 feet long and 2 feet deep. Referring to Table 4 it is found that a spillway having a length of 16 feet and a depth or head on crest of 2 feet has a discharge capacity of 144.8 cubic feet per second. Subtracting this amount from 293 cubic feet per second (the total computed rate of run-off for the watershed) there is left 148 cubic feet per second to be provided for in the culvert.

Referring to figure 19, it is found that a box culvert size 2-1/2 x 2-1/2 feet under a head of 20 feet will carry 160 cubic feet per second which is slightly in excess of the amount required. It is recommended that a culvert of this size be used.

If it is desired to use a pipe culvert, it will be found by referring to figure 18 that a pipe between 30 and 36 inches diameter would be required and the larger pipe should be selected.

APPENDIX TO INSTRUCTIONS OF GULLY CONTROL

TABLE A

NUMBER OF STRANDS OF NO. 9 WIRE IN
CABLES OF CABLE AND WOVEN WIRE DAMS

Height of dam feet	Width of dam in feet					
	5	10	15	20	25	30
2	2	2	3	4	5	6
3	3	5	7	10	12	14
4	4	8	13	17	21	25
5	7	13	20	26	34	40
6	10	19	28	38	47	57

TABLE B

FOR OTHER SIZES OF WIRE MULTIPLY BY
FOLLOWING FACTORS

Size wire	Factor
No. 5	0.53
" 6	0.61
" 7	0.71
" 8	0.84
" 9	1.00
" 10	1.23
" 11	1.50
" 12	1.86
" 13	2.46

For example; if it is desired to use No. 11 wire instead of No. 9, then 1.5 as many strands would be required.